MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

The Field of Engineering

Today, probably because of the fundamental law of division of labor, there is an increasing tendency to separate discovery and application. Thus we speak of the fields of pure science and of applied science as though they were unrelated. It should be remembered that knowledge, scientific or otherwise, is useless unless it can be applied to human problems of some kind. A learned man who does not use his knowledge to increase in some way the sum of human happiness is merely an object of curiosity. The field of work wherein scientific knowledge is applied to industrial problems has become known as the field of engineering. The tendency to broaden this definition in recent years has been quite marked. Used originally to designate the design, construction, and operation of industrial works, it has been extended to cover practically everything in the way of industrial work, including the problems of humanity so far as they are affected by modern industrial methods.

DEXTER S. KIMBALL

(From Address at Franklin Institute Centennial, 1924)

MARCH 1925

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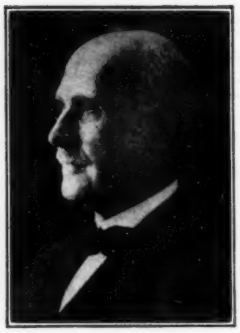
Ernest Robinson

H. D. Savage



A. W. Smith

Francis Hodgkinson

P. W. Bridgman

Contributors to this Issue

Albert W. Smith, Dean Emeritus of mechanical engineering at Cornell University, is the author of the life of John E. Sweet, the first chapter of which appears as the leading article in this issue. Dean Smith is a graduate of Cornell University, class of 1878. After serving as a professor of machine design at the University of Wisconsin and as professor of mechanical engineering at Leland Stanford University, he became dean of Sibley College of Mechanical Engineering at Cornell University in 1904 and held that position until 1920 when he took over the duties of acting president of the University for one year. He retired in 1921.

* * * * *

P. W. Bridgman, author of the paper on Properties of Matter Under High Pressure, has made extensive researches in high pressure. He is professor of physics at Harvard University. Dr. Bridgman is a graduate of Harvard holding the degrees of A.B., A.M. and Ph.D. From 1908 to 1910 he held the research Fellowship at Harvard and then became an instructor in the physics department. Three years later he became assistant professor in that department and in 1919 was appointed to a full professorship.

* * * * *

Ernest Robinson presents in this issue a paper on Equipment Used for Aerial Surveying. Mr. Robinson was born in Birmingham, England, and attended the King Edward Grammar School and the Mason Science College. In this country Mr. Robinson has been connected with the Standard Engineer Co., Hale & Kilburn Manufacturing Co., Dunlap Wire Wheel Co., the Tabulating Machine Co., and the Royal Typewriter Co. He is at present vice-president of the Fairchild Aerial Camera Corporation.

* * * * *

C. W. E. Clarke, power engineer with Dwight P. Robinson & Co., New York City, contributes an article on Air Preheaters. Mr. Clarke's early associations were in Chicago where he designed several power and refrigerating plants for Armour & Co. Later as chief draftsman for Sargent & Lundy, the design specifications and construction work for installations aggregating 100,000 kw. in the Chicago district were completed under his direction. In 1907 he became associated with the New York Central Lines and was in charge of mechanical engineering in the New York electrical zone until 1910. Between that time and the time of his joining Dwight P. Robinson & Co., Mr. Clarke was connected with the firm of Stone & Webster.

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J. G. Coutant, author of The Unit-Coal Pulverizing Plant and Its Operation, is fuel expert with the Furnace Engineering Co., New York. Mr. Coutant became interested in powdered fuel in 1907. He purchased a Quigley plant for the Lima Locomotive Works in 1912–13 and the following year conducted a powdered-coal research for the Railway Materials Co., Chicago. He was connected with the Quigley Co. during 1916 and 1917 and then became advisory engineer for the Société de l'Utilisation Combustibles Pulverulents. In 1920 Mr. Coutant became European resident engineer for the Quigley Co. for pulverized-fuel installations in various countries and in 1922 was appointed chief engineer of the department of powdered coal, Ste. Am. Foyers Automatiques, Paris.

* * * * *

Francis Hodgkinson, author of Large Steam Turbines, is chief engineer of the South Philadelphia Works of the Westinghouse Electric & Manufacturing Co., in charge of all of the engineering departments. Mr. Hodgkinson was educated in the Royal Naval School at New Cross, London, England. He served his apprenticeship with Clayton & Shuttleworth, agricultural engineers in Lincoln, England. In 1885 he became associated with C. A. Parsons & Co., where he remained until 1890. During this time he attended night courses at Durham University. In 1896 he took charge of the engineering and designing of Parsons' type turbines for the Westinghouse Machine Co. This position he still maintains and in addition was appointed to the position he now holds in 1916.

* * * * *

G. G. Bell, who contributes an article on Turbine and Boiler-Room Auxiliaries, was graduated from Toronto University in 1905 as an electrical engineer. From 1908 to 1910 he was engaged in structural drafting and design for the Canadian Bridge Co., Walkerville, Ont., and for a like period of time handled structural and hydraulic engineering for the Sawyer-Moulton Co., Portland, Me. Mr. Bell first became associated with the West Penn Power Co. in March, 1912. He is now manager of power development.

* * * * *

Robert Cramer, consulting engineer in Milwaukee, Wis., is the author of the paper on Uniflow and Compound Duoflow Engines. Mr. Cramer was born in Vienna, Austria, where he was educated at the Weiner Neustadt. He came to this country in 1903 as draftsman and designer in the steam turbine department of the Allis-Chalmers Co. He has been in the consulting field since 1921.

* * * * *

T. A. Peebles, chief engineer of the Hagan Corporation, Pittsburgh, Pa., writes on Combustion Control. Mr. Peebles was born in Scotland. He was educated in this country and is a 1906 graduate from the University of Illinois. For two years he was connected with the Crystal Falls Mining Co. and with W. L. Fergus, consulting engineer in Chicago, resigning to accept a position with the Green Engineering Co. of Chicago. From 1914 to 1917, Mr. Peebles was assistant manager of the stoker department of the Westinghouse Electric & Manufacturing Co., when he became chief engineer of the Hagan Corporation.

* * * * *

Harlow D. Savage whose paper on Water-Cooled Furnaces is included in this issue, is vice-president of the Combustion Engineering Corporation, New York City. Colonel Savage, prior to his entrance into the pulverized-fuel field, devoted most of his time to the building and selling of refractory materials. As the active head of the Ashland Fire Brick Co. he designed and installed the first completely electrified plant in the world. In 1914 he became vice-president of the American Arch Co. and two years later vice-president of the Locomotive Pulverized Fuel Co. When the Combustion Engineering Corporation purchased the Lopulco Pulverized Fuel Systems in 1920, Colonel Savage became associated with the organization as the directing head of the pulverized-fuel division. He has since become vice-president.

MECHANICAL ENGINEERING

Volume 47 March, 1925 No. 3

John Edson Sweet—The Man[1]

Chapter I of the Life of John Edson Sweet by Dean Albert W. Smith, Published this Month by The American Society of Mechanical Engineers

A DESIRE for accuracy and perfection and a love for beauty of design marked the works of John Edson Sweet. A passion for service motivated his life. The American Society of Mechanical Engineers stands today as a vital monument to his ideals of service, for he founded the Society in order that men might be of greater mutual help to each other.

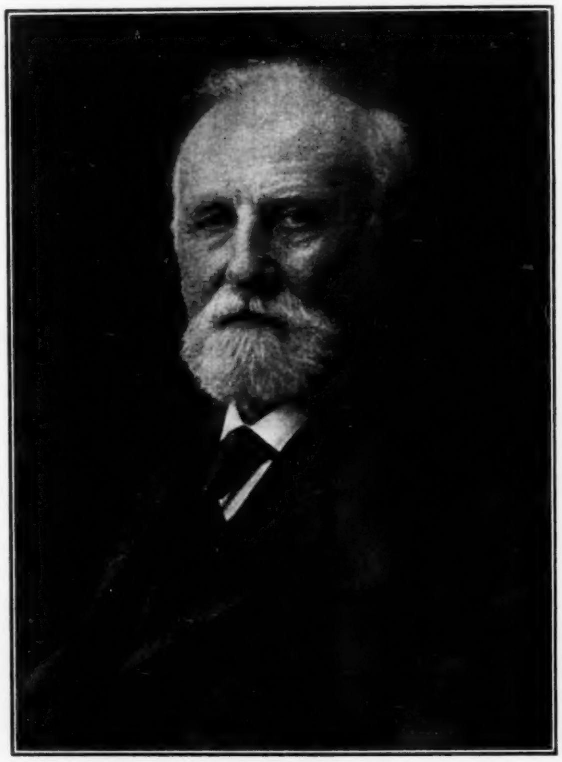
It is in this same spirit of service that the Society now offers the biography of John Edson Sweet, for in truth, "no book is more stimulating than the history of a successful and devoted life." The book has been written by Albert W. Smith, Dean Emeritus of Mechanical Engineering of Sibley College, a member since his early days of the informal organization which grew up around Sweet—known as "Professor Sweet's Boys"—and impregnated with the ideals for which their leader stood. He has written with rare feeling and with faithfulness to his subject. The sympathetic understanding which existed between the two men, and Dean Smith's knowledge of the technical problems which Sweet met and solved throughout his life, added to a literary ability which has long been evident, have given him admirable qualifications as the biographer of John Edson Sweet.

The first chapter of the biography appears below. It describes John Edson Sweet—The Man, the influence of whose life gathers momentum throughout the years. For his torch lit the lives of young men who have carried his ideals to the corners of the earth, and he truly lives in their continual striving to attain the perfection he, too, sought for. The chapter will recall his vivid personality to all who knew him. And to those who never had that honored privilege, it will present a firm upstanding character—an engineer who bore modestly the highest honors of his profession, a man of whom engineers will always be proud to say, "He was one of us."

Lack of space prohibits the inclusion of more of this valuable biography in this issue of MECHANICAL ENGINEERING. The book gives not only the biographer's account of the life of Sweet but, through selected addresses and travel letters it gives a first-person picture as well, of his ideas of life, of work, of art, and of his relations with his fellow man.

The biography of John Edson Sweet is a story of achievement in engineering and of influence upon men. It is published by The American Society of Mechanical Engineers under the guidance of the following Committee: E. N. Trump, Chairman; F. A. Halsey, A. W. Smith, Ambrose Swasey and F. G. Tallman.

[1] JOHN EDSON SWEET. By Dean Albert W. Smith. Subscription edition by The American Society of Mechanical Engineers, New York, 1925. Illustrated. 220 pp. Two bindings. $3.75 and $7.50.



JOHN EDSON SWEET

Chapter I: The Man

Men live after their death; they live not only in their writings or their chronicled history, but still more in that unwritten memorial exhibited in a school of pupils who trace their moral parentage to them.—NEWMAN.

JOHN EDSON SWEET loved his fellow men, was forgetful of self in his anxiety to serve others, was filled with enthusiasm for high ideals of character and work, scorned the second best in all his strivings, and was blessed with a rare sense of humor and with a genius for friendship.

Usually a man, in character, is a composite of qualities, some good, some bad, received through inheritance and modified by circumstance and his own conscious effort; his chance for effective life depends on the resultant of these qualities. But sometimes the ruler of human destinies nods, and a specification goes through with all good or all bad qualities left out; then a criminal or a saint comes to earth for its bane or blessing. It is certainly true that selfishness, which includes almost all that is bad, was left out of the nature of this man.

He expressed the dominant motive of his professional career when he said: "I cannot recall to mind ever starting on a job without thinking out how to do it better than it had been done before." This motive influenced him when, in 1840 at the age of eight, he made a boot-jack—a necessity in those days—that was right side up either way; it influenced him in all the larger undertakings of his maturity and later life.

His character appears in the legend, "Visitors Always Welcome," which is cut into the stone arch above the entrance to the Straight Line Engine Works in Syracuse. All that he had to give, and it was a large and precious store, he gave, freely and with no thought of return, to all earnest comers.

Dr. Charles R. Brown,[1] in one of his "Yale Talks" said: "There was a man named Peter in the Early Church who had come to be known as an upright, downright, outright sort of a Christian. He had done so many good deeds, he had spoken so many true and timely words, he was so simple, unaffected, and genuine in his whole make-up that the people came to believe that his very shadow would do a man good. So they brought sick people into the streets that at least Peter's shadow might fall on them as he passed by. We are not told that any sick people were actually healed in that way. . . . It was their testimony to the silent, powerful contagion of a thoroughly good life. . . . Now the most potent and lasting influence is just like that. It is not so much what you say; it is not so much what you do; it is what you are that does the business."

[1] Dean of the School of Religion of Yale University.

It seems almost as if Dr. Brown had spoken of Professor Sweet, for it was just such unconscious influence that flowed from him to those associated with him, so that wherever his shadow fell good came of it. It is certain that many of us who knew him sought the place of his shadow whenever we could.

Few of his friends ever heard him speak of religion; his religion was not a matter of words, but of life. He lived the Golden Rule, but never talked about it.

He was peculiarly sensitive to kindly praise and his emotions were easily stirred. His eyes would fill and his voice would break when any one spoke appreciatively of his accomplishments.

He believed that men should work because of enthusiasm for the task and its results, or because of loyalty to some enthusiastic man who could produce results. Once in the early days at the Straight Line shop the young foreman thought it necessary to have shop rules posted so that the workmen might be held to strict whistle time and to other minor details of conduct. When these rules were submitted to Professor, as we affectionately called him, he read them and said gently: "I don't believe we need them." The foreman said: "There is nothing in these rules that I don't conform to personally, and isn't it reasonable that the others should conform also?" He smiled an unconvinced smile and allowed the rules to be posted; he knew that it was unimportant, anyway. The printed cards grew dusty and illegible and finally found their way into the waste-basket. Meanwhile all the real men in the shop gave always the best that was in them because of their loyalty to this man; a far stronger motive than any printed code could furnish.

Yet with all his gentleness he never hesitated to stand for what was right, and he guarded carefully the interests of the stockholders of the Straight Line Engine Company. His method, however, was that of the inspirer of loyalty rather than that of the driver, and he always paid a fair wage. But once the molders struck; he paid them in full, refused to discuss grievances, and waited till they were ready to come back on the old, fair terms, which they did presently, and there were no more strikes. He was the fairest of men, and he wished to hold an even balance between justice to the men and justice to the stockholders. If profits had exceeded this standard—which they never did—he would have been the first to suggest dividing the excess with the workmen. He would never allow his personal salary to be raised above a rate corresponding to that of a competent foreman; he did not care for money except to make honest payment for the necessaries of simple living.

In one thing only did he wish to go beyond the standards of his neighbors; he loved travel; he sums up his experience as follows: "I have traveled a good deal; probably nearer two hundred thousand miles than one. . . . I have crossed the Atlantic fifteen times, been in ten seas and twenty-two countries." But all of this travel was paid for out of careful savings from his small income. Thus he was able to see, to his great delight, the wonderful things that nature has wrought, as well as those that have come from the hands of the great artists and builders and engineers of the race.

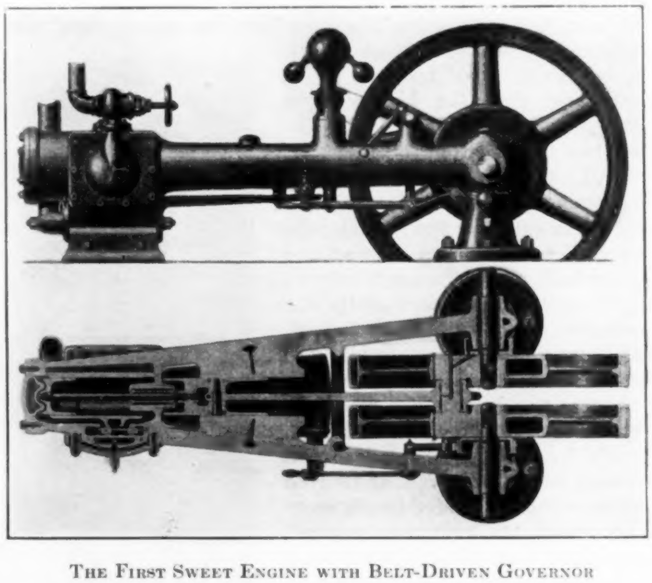
He had an inborn feeling for beauty in art, especially in architecture; of Venice he said: "It was a gem to me when I first saw it, and it has grown brighter and brighter each time that I have seen it since." It was beauty of proportion rather than beauty of ornamentation that made the strongest appeal to him. He read Ruskin with understanding and delight, and it was doubtless reading "Stones of Venice" that awakened his desire to see Europe with its art treasures.

Out of this inherent enthusiasm for beauty of proportion grew his characteristic ideas of proportion in machines. In 1874 in a public address he said: "A straight line, if it end gracefully and properly, is a hard one to improve upon for machine outlines; and until you can handle the straight line as a master, do not hazard your reputation on curved lines." This fundamental principle, together with many others first thought out by him, appears in all his designs; and, through those who learned from him, they appear in all the best designs of machines of the present time. Thus his professional influence was far-reaching, though few now recognize the source of these ideas because their originator was so modest and so generous, and because they were transmitted through so many minds that their origin has become obscured.

He had remarkable capacity for seeing into the very heart of a problem; for blowing away all chaff and uncovering perhaps some real grain, perhaps just nothing at all.

Once a man came to him with an invention which he explained at length; Professor Sweet listened with his unfailing patience and said: "Well, it seems to be a mighty good way to do a thing that doesn't need to be done." There was nothing left to be said.

Another man came to him with a scheme to apply ball bearings to buggy axles to reduce the tractive force. Professor Sweet gave his opinion as follows: "The axles of a buggy are of steel, well fitted to cast-iron sleeves, and presumably well lubricated. If you should place a buggy on a smooth floor, and, with a sensitive spring scale determine the force necessary to move it and to keep it moving, you would find this force so small that if the ball bearings saved all the corresponding power, the expense for them would not be justified." Then, having demolished the scheme, he made, as was his way, some constructive suggestions. He said: "The resistance to a moving vehicle is chiefly at the wheel rim, and can be reduced most effectively by making better roads." This was long before the modern "Good Roads" movement, and was therefore prophetic, like so much of his thought.



The First Sweet Engine with Belt-Driven Governor

This gift of clear vision is illustrated also by the following occurrence. An eminent mathematical teacher while calling on Professor Sweet spoke of a geometrical problem that he had assigned to advanced classes. He stated the problem as follows: "Given three circles of different diameters in any relative position in a plane, draw the two common tangents to each pair of circles until they intersect; these three intersections will lie in a straight line." After thinking for a few minutes, Professor Sweet said: "Yes, I can see that that is true; in fact it seems self-evident." "But," said the somewhat nettled mathematician, "perhaps you don't understand; it is quite a difficult problem." Professor Sweet answered: "Let the circles be replaced by spheres resting on a plane; let the tangents rotate to form cones tangent to the spheres and to the plane; the apexes of the cones will lie in the plane. Let another plane rest on the spheres; it will be tangent to the cones also, and hence will contain their apexes; therefore the apexes of the three cones are in both planes and hence must be in their intersection, which must also be a straight line." The mathematician saw and went away wondering.

The two following stories from a letter written by Mr. E. J. Armstrong show that Professor Sweet was a true democrat. "Once in his home, and when I was young, he took my silk hat from its insecure place on the hall rack and, carrying it in both hands as if it were the most fragile of things, placed it in the middle of a bed in an adjacent room. I do not think he knew that I saw him, and I am sure he did not intend a lesson; it was probably his kindly solicitude only as far as his intent was concerned; but there was something in his way of doing it that hit me hard; and I went

straight from his house to a hat store, and I have never worn a silk hat since." Was it not Professor Sweet's spirit of democracy made evident that made Mr. Armstrong discard the insignia of class distinction?

Another story from Mr. Armstrong is as follows: One day in the Straight Line shop a machinist needed a chain for handling some heavy machine part. In taking it across the shop he dragged it—perhaps accidentally, perhaps intentionally—through a pile of rubbish which had been swept up carefully and laboriously by the janitor, a rather infirm old man; the rubbish was scattered and a thoughtless laugh went 'round. Professor Sweet, who was present, flushed and went to the machinist and spoke to him so that no one else could hear, and then went into the office. The offender borrowed the janitor's broom at once and restored the rubbish to an orderly heap, and ever after was more thoughtful, as was every other man in the shop. This power for gentle influence upon character was perhaps the finest of his many fine qualities; where his shadow fell, good came.

Professor's sense of humor and love of fun were a delight to his friends and a source of pleasure to him throughout his life.

His brother, William A. Sweet, was a man of distinguished ability, a successful steel manufacturer and business man; but he was aggressive, vociferous, and confident of his opinions; thus he was a great contrast to Professor, who was quiet and almost overmodest. One day a man came in to consult Professor about an invention. He said: "I came to you for advice because they tell me that you know everything." "Oh, no," said he, "that's my brother Bill." Those who knew him can imagine the twinkle in his eyes and his quiet chuckle when he said this.

A man came into the office soliciting orders for shirts; when he had told his story, Professor said with a twinkle: "But I have another shirt at home already."

In an article contributed to a technical journal he spoke of something as "as much out of place as a cold-chisel in a barber shop."

One evening in 1906 or 1907, a meeting of the Technology Club of Syracuse was held, and Professor Sweet, who had been a member of the club for many years, was present. The meeting was devoted to the discussion of air cooling versus water cooling for automobile engines. Two eminent engineers, advocates of the respective systems, led in the debate, while members of the club joined in the discussion, which waxed hot and developed decided differences of opinion as to the proper temperatures for cylinder operation. At last, about eleven o'clock, Professor Sweet rose, and we all expected to hear some original and interesting ideas on motor engineering. He addressed the chair in his peculiar, high-pitched voice, and said: "It seems to me that the whole point of this matter of air cooling as compared with water cooling turns on whether you like your pistons fried or boiled." He sat down amid roars of laughter and a motion to adjourn was immediately carried.[1] Professor knew so well that, beyond certain limits, debate, like friction, only develops heat with no useful work done; he also knew that a hearty laugh restores equilibrium and sends the debaters home happy, though unconvinced.

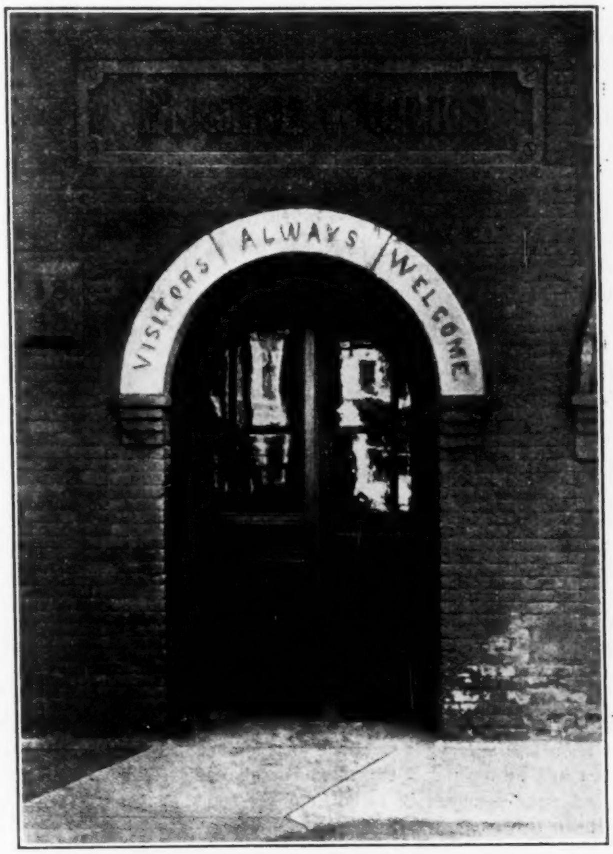
Once, long after "Visitors Always Welcome" had appeared over the Straight Line entrance, Professor Sweet had occasion to visit a certain manufacturing plant. On the door he found this inscription: "Keep out and avoid the unpleasantness of being put out." After he had presented his credentials and been admitted, he referred to the inscription and asked: "What is it that you have here that you are so ashamed to have people see?"

He told with keen enjoyment of a joker in his native village who "had two yokes of oxen drawing interest." He also told of a competitor of Baron Munchausen who told of building a log house that was so tight that the fire wouldn't draw until a gimlet hole was bored in the window sash.

As far as he ever hated anything, he hated war. He could never be convinced that it was right for young men to lay down their lives in battle; he believed that a human life just on the brink of accomplishment was more precious than all the questions over which wars are fought.

His desire to avoid strife is illustrated by the following story. One noon hour while he was working in England, he went through a part of the manufacturing plant seeking, as was his habit, for some new thing. A man came to him and said: "You have no business here; if you come here again, I'll knock you head off." "No, you won't," said he under the impulse of the moment, "I'll come here as often as I want to." "Well, how did it come out?" asked a man to whom Professor told the story. "Oh, I never wanted to go there again," said he with a quiet laugh.

He had a horror of the use of intoxicants. He tells of an experience when he was about five years old. With his father and mother he was on a trip and they had stopped at a hotel at Massena Springs. His mother was taken sick and asked his father to get her some wine, at which he was horrified. This feeling appeared so early that he believed that his temperance ideas must have been inherited. In this as in other things his influence was chiefly through example; but on one occasion he spoke out what was in his mind. It was in an address to the students of Sibley College about 1874. He said: ". . . but bear this in mind: you cannot make first-class mechanics or mechanical engineers and first-class drunkards at the same time. Many a man has tried it, and when one starts with the idea of doing both, the drunkard always comes out ahead."



Entrance to the Straight Line Engine Works

In a milder way he disapproved of smoking. It was only in later life at the dinners in honor of his birthdays that he insisted on paying for cigars for the "Boys" who, for some reason unknown to him, wished to smoke them.

All through life he advocated discussion as a means of increasing understanding. Verbal strife was the only kind of strife of which he approved; he knew that out of it come new ideas, the raw material of effective thinking; while by it no lives are lost or injuries sustained that reduce capacity for productive effort. Once when one of the "Boys" who had become a teacher of engineering bade him good-bye after a short visit, he said: "Tell your students as a message from me, *to talk over their work with each other.*"

While he was a teacher at Cornell University he organized "The Mechanical Association." All students of Sibley College were members, and weekly meetings were held on Friday with

[1] This story comes from Prof. F. E. Cardullo, now chief engineer of the G. A. Gray Company, of Cincinnati, Ohio.

quite full attendance. Professor Sweet was the life of these meetings, for he always had questions to ask that stimulated interest and started discussion; also he always had illuminating answers to student queries and wise and kindly criticism for student theories.

It was doubtless partly due to Professor Sweet's belief in the beneficial effects of discussion that he became the moving spirit in the founding of The American Society of Mechanical Engineers. Of this he himself said shortly before his death: "Probably the most important thing I have done was to set the ball rolling for the organization of the A.S.M.E. that now (in 1916) has nearly 7000 members[1] scattered throughout the inhabited surface of the earth."

His wisdom and the prophetic quality of his mind were obvious to all who knew him well. The concluding paragraph of his address as retiring President of The American Society of Mechanical Engineers in November, 1884, was: "Let us hope that the day may not be far away when the man who knows what to do and how to to do it, will stand at least equal to the man who knows what has been done and who did it."

It is significant that years later David Starr Jordan, then President of Stanford University, said: "Wisdom is knowing what to do next; virtue is doing it."

The thought of these two epigrams is similar, for Professor Sweet surely had it in mind that he who knows what to do and how to do it can be depended on for action. A man might have all the accumulation of human knowledge (if that were possible) and yet might never do a worthy deed; a man might be wise in knowing what to do next and yet might not know how to do it. In either case he would cumber the earth.

In an address before The Mechanical Association of Sibley College in 1874 Professor Sweet said: "You will be paid for what you do, not for what you know." His faith was in doing things and in doing them better than they had been done before.

On one occasion some one asked: "Professor, what is an engineer?" He replied: "Perhaps I can answer best by an illustration. They built a bridge recently, and when the design was made the stresses in all members were figured with great accuracy for the assumed value and character of loading; the figures were carefully checked to eliminate errors. Then a man came along and said: 'Multiply all stresses by six, and design the members to correspond.' That man was an engineer. Any mathematician can figure stresses; any draftsman can select steel forms suitable for known stresses; but it takes an engineer to tell what to multiply by." This was Professor Sweet's striking way of saying that in engineering undertakings the final appeal is always to some man whose judgment has been trained; that it is the engineer who estimates the things that can't be figured. Professor Sweet often quoted Mr. Bement, the eminent designer of large machine tools, of Philadelphia, who said: "I think it useful to figure the strength of machine parts because the results are suggestive to the designer." This seems a strange statement to those who think that a design is finished when the stresses are calculated, but Professor Sweet knew that it was a wise saying; for it is the engineer who makes the final decisions and takes the responsibility.

In the latter part of the last century there was much scornful misunderstanding between the trained theorist and the skilled workman. This tended to increase with the development of the mathematical and scientific basis of engineering; it tended to decrease as trained engineers proved their usefulness. The resultant tendency has been toward the establishment of mutual appreciation and coöperation; but even yet the process is not complete.

Mr. Sweet, in a communication to London *Engineering* in 1871, expressed himself with prophetic understanding on this subject substantially as follows: Bearing in mind that thought and scientific theory cannot produce a successful engine or machine without the aid of skilled workmen, and that workmen however skilled are helpless without the thought of the trained designer, it would seem that the theorist and the workman are dependent on each other, each deserving his share of credit; and that whatsoever can be done to harmonize the two, in feeling as well as in work, will tend toward the progress and welfare of both.

All through his life, in addresses, in published articles, and in conversation, he urged coöperation of theoretically trained men with those who work at skilled trades with their hands; his sympathy was always strongly with the skilled, thoughtful craftsman, for whom he asked recognition and due credit; but he was always highly appreciative of results attained through application of higher mathematics to more abstruse problems. Even as he believed that one of the most important problems in machine design is reduction to minimum of waste by friction, so in the realm of ideas he preached the gospel of elimination of waste due to antagonism.

Mr. Sweet's attitude of kindly helpfulness toward struggling thinkers with inventive impulses is shown in another article in the journal cited above, also in 1871. He says in substance: Engineers are sure to be consulted on the practicability of schemer's contrivances, some of which will be of the "perpetual-motion" class. Often in such cases the schemer is dismissed with a sneer; but that is not right or fair. He who has not the ability to analyze an invention and to point out the fallacy has no right to say that there is a fallacy. To say that a certain device will not work because its working is not in accordance with the laws of mechanics, is not an explanation. When a counselor cannot make his client understand why his invention will not work, it may be because he does not know himself or because he has not the faculty of clear explanation, rather than because of the stupidity of his client.

He had a wonderful gift for making friends and for holding them; none of his students, none of those who worked with him or for him, ever forgot him.

Professor Sweet was of medium height and slight build; his movements when at work were quick and without lost motion.

His face in thoughtful times was usually grave, and his eyes were apt to narrow during the development of ideas; in repose his expression often fell into sadness, but it flashed into humorous lines with the occasion. His eyes were bright and expressive, and filled easily with tears.

He was never strong physically, and his accomplishments resulted from the steadfast spirit that would not let him rest.

In November, 1870, Mr. Sweet married Miss Caroline V. Hawthorn, whose geniality, culture, and other social qualities helped to make their home in Ithaca a place to which students felt it a privilege to go, and from which they carried memories of kindly hospitality. Mrs. Sweet died in 1887 after a lingering illness throughout which Professor Sweet devoted himself unreservedly to her welfare, providing everything that physicians or travel or his own tender care could contribute to prolongation of her life and the mitigation of pain.

In 1889 he married Miss Irene A. Clark, of Syracuse, who entered into the spirit of all of his interests, who husbanded his income, and who was an enthusiastic, helpful, and interesting companion on all of his journeyings as well as a charming hostess in his home.

In 1914 the John Fritz Medal was awarded to Professor Sweet "for his achievements in machine design, and for his pioneer work in applying sound engineering principles to the construction and development of the high-speed engine."

In the same year the honorary degree of Doctor of Engineering was conferred upon him by Syracuse University.

The last day of Professor Sweet's life was typical of all his days. Though he was eighty-three years of age, he went in the forenoon to the office of the Straight Line Engine Company. Just before noon there came to the office a man from far away, who knew Professor only through his articles in the *American Machinist*, to ask advice about a valve gear that he had designed. They had talked for only a few minutes when the carriage came according to custom and carried Professor home for the noon hour, an engagement having been made for another meeting at three o'clock. After luncheon Professor returned to the office, but by two o'clock was suffering severe pain. W. C. Brown, one of Professor Sweet's "Boys," who was at the works with him, took him home in his car. On the way, despite acute suffering, his whole thought was to tell Brown, for transmission to the visitor, what he would have said if he had been able to keep the engagement. At eight o'clock he died. His anxiety was that he should not fail in helpfulness. It was a fitting close to a beautiful, unselfish life.

Though his direct shadow does not fall here now, yet through those who felt his influence many shadows fall daily and good is still coming to men because he lived.

[1] This number had increased in 1924 to over sixteen thousand.

Properties of Matter Under High Pressure[1]

Phenomena Observed when Using Hydrostatic Pressures of the Order of Several Hundred Thousand Pounds per Square Inch—Methods of Packing and of Measuring Pressures—Conditions under which Materials Rupture under High Pressure, Etc.

By P. W. Bridgman,[2] Cambridge, Mass.

THE pressures of steam-engineering practice are of the order of magnitude of hundreds of pounds to the square inch. The next order is that of the pressures employed in hydraulic presses where there is no difficulty from high temperatures and where pressures may run up to several thousand pounds. The next stage is the range of tens of thousands of pounds, such as we meet in heavy guns.

The pressures I wish to discuss are higher still, of the order of magnitude of hundreds of thousands of pounds per square inch. The highest pressure I have had experience with is 600,000 lb. per sq. in. The highest I have succeeded in measuring with considerable precision is perhaps 300,000 lb. per sq. in. As a routine matter of everyday work, in ordinary liquids it is possible to reach pressures of 200,000 lb. per sq. in. without having the apparatus show any deterioration. I might say that this is the consideration that sets the limit for the pressures that can be reached.

Under these pressures we begin to get effects of a different character from the effects obtained at low pressure. Under low pressures, matter chiefly shows only a desire to get out of the way as rapidly as possible. The steam-engine piston moves, but the material experiences no particular modification. When, however, we get to pressures of the order of hundreds of thousands of pounds to the square inch, the properties of matter are actually beginning to change by a significant amount. By measuring these changes, although they are small, we get an indication of how matter will act under higher pressures as well as a useful idea of the structure of matter itself.

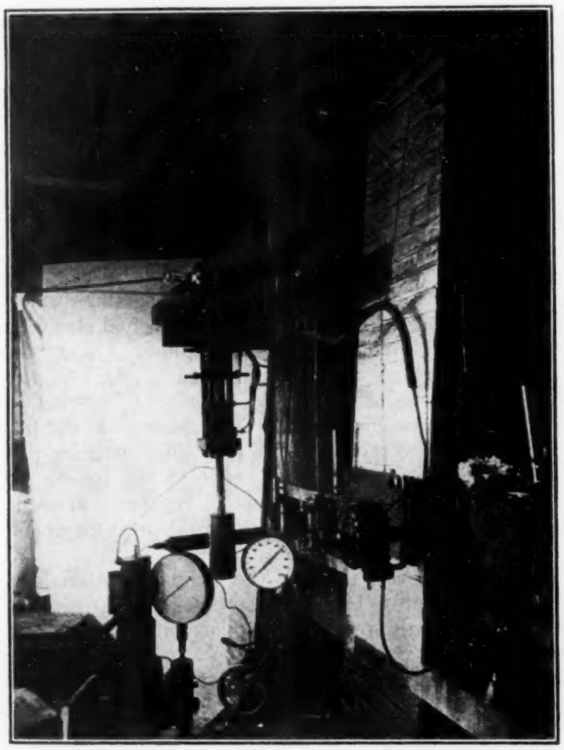


Fig. 1 General Set-Up of Apparatus for Producing High Pressure

We must not expect too much even of these pressures of hundreds of thousands of pounds. The most that we can expect is to make the molecule uncomfortable; it shrinks and rearranges itself. We must go to the billions of atmospheres of the astronomer before the atom becomes so uncomfortable that it falls to pieces. With still higher pressures, the electrons possibly might become uncomfortable and disintegrate.

Method of Producing High Pressures

The method of producing pressures is simple. Take a large, thick block of steel, bore a hole into it and put liquid into the hole. Then put into the top of the hole a plug which will not leak, and push on the plug.

A limit to the high pressure obtainable is set by two things: the leaking of the plug and the yielding of the steel container. The second of these conditions imposes a restriction on practice which at first sight seems curious. Most people who ask about these experiments are prepared to expect an enormous apparatus to deal with this high pressure. That is not true of the apparatus actually employed. The higher the pressure you want to get in any liquid, the smaller you must make the apparatus for the simple reason that you cannot heat-treat a large mass of steel. I began with apparatus on a much larger scale than the apparatus I finished with: I began with a cylinder 6 in. in diameter, and I recently ended with one $^1/_4$ in. in diameter.

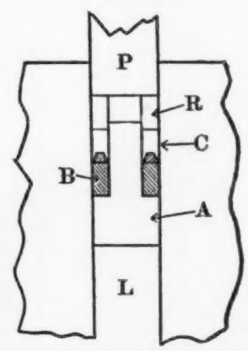


Fig. 2 General Principle of the Packing by which the Pressure in the Packing B is Always Kept Higher Than That in the Liquid at L

Fig. 1 shows the general set-up of the apparatus, which consists essentially of a chamber in which pressure is produced by a plunger, a mechanism for pushing the plunger into the chamber, a tube connecting the chamber in which pressure is produced with a second chamber adapted to the particular investigation, and a pressure gage. The second chamber is the only part of the apparatus that need be varied for different experiments. The mechanism of course may be anything that will furnish a force of the required intensity and exert it over a long-enough distance. It has been usual in previous high-pressure work to use a screw to drive the piston. When, however, the pressure to be produced becomes high, the screw becomes very inefficient, and it is highly desirable to replace it with a hydraulic press. To avoid bulky apparatus, it is desirable to actuate the press with liquid at a fairly high pressure, say, 1000 kg. per sq. cm. The hydraulic press may have a diameter of, say, $2^1/_2$ in. and therefore permit of a pressure of 25,000 kg. per sq. cm. on a $^1/_2$-in. piston, the size usually employed.

Fig. 2 shows a most important part of the apparatus, the packing of the high-pressure piston which pushes the plug into the first high-pressure chamber. The piston P pushes the plug A through the medium of the hardened ring R, the cupped washer of soft steel C, and the rubber packing B. The liquid is compressed below A at L. The plug A is provided with a stem which is long enough to reach into the ring R, but not long enough to reach to the piston P. If now we consider the equilibrium of A, we see that the fluid pressure over the lower end of A must be balanced by the pressure exerted by the packing B on an area less than that of A by the area of the unsupported stem. The result is that the hydrostatic pressure in the packing B per unit area is always a certain percentage higher than that in the liquid, so that the liquid can never leak past the piston. This principle is capable of manifold modification, but always there must be somewhere an area unexposed

[1] Lecture delivered at the Annual Meeting of The American Society of Mechanical Engineers, New York, Dec. 4, 1924. In revising for publication the sections on rupture have been expanded, and others, more particularly those on polymorphic transitions of pressure, have been contracted.

[2] Professor of Physics, Harvard University.

to the action of pressure, so that the hydrostatic pressure in the packing itself may be always higher than that in the liquid.

Measurement of Pressure—Primary Gage

In a new field everything has to be done from the beginning. I had to find some absolute way of measuring the pressure. The simplest device was of the free-piston-gage type.

A common feature of all previous gages of this type is that of the piston fitting accurately in the cylinder, which is subjected to pressure on the inside only. The distortion produced by the pressure is therefore a compression of the piston accompanied by a stretching of the cylinder, the resultant effect being an increase in the breadth of the crack between piston and cylinder. The leak, therefore, at higher pressures increases because of the increased pressure expelling the liquid and the increased breadth of the crack.

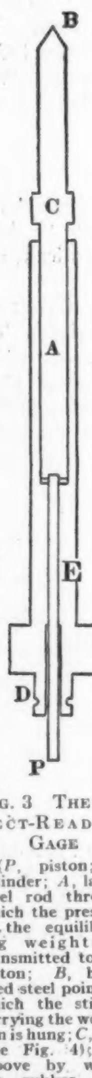


Fig. 3 The Direct-Reading Gage

(P, piston; E, cylinder; A, larger steel rod through which the pressure of the equilibrating weights is transmitted to the piston; B, hardened steel point on which the stirrup carrying the weight pan is hung; C, stop (see Fig. 4); D, groove by which the rubber tube containing the viscous mixture of molasses and glycerine is attached.)

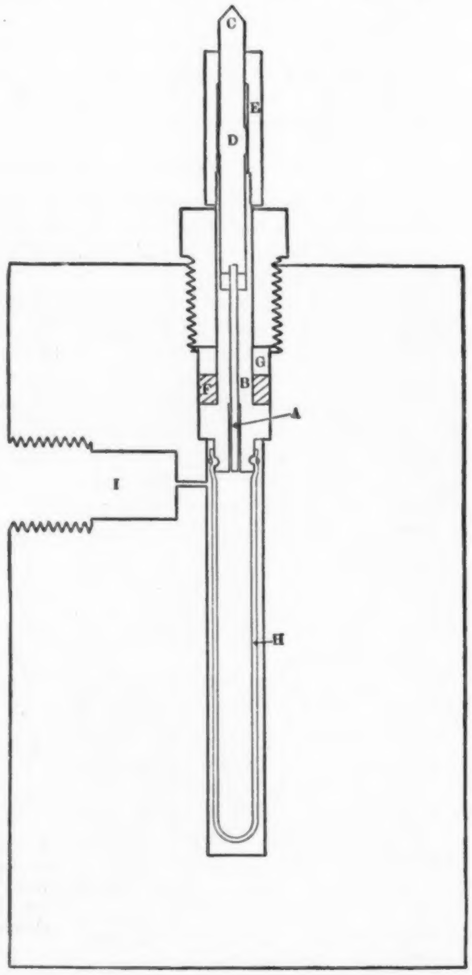


Fig. 4 Gage of Fig. 3 in Place in a Large Steel Block

(A, piston; B, cylinder; C, hardened steel point on which the equilibrating weights are hung; D, stop, preventing too long a stroke of the piston either up or down. In this stop is placed the rod by which the rotary motion is imparted to the piston to increase sensitiveness. E, guide to insure the upper part of the piston's moving rigidly in a straight line. F, rubber packing; G, steel washer retaining the rubber packing; H, easily collapsible rubber tube containing the viscous mixture of molasses and glycerine; I, connection to the high-pressure pump. The thin mixture of water and glycerine transmitting the pressure is injected through this hole, acts on the outside of the rubber tube H, and so transmits the pressure to the piston A.)

This effect is avoided in the gage used in this work by subjecting the cylinder in which the piston plays to pressure on the outside as well as on the inside. It is well known that a cylinder subjected to the same pressure externally and internally shrinks to the same extent as a solid cylinder subjected to the same external pressure. By properly decreasing the external pressure on the hollow cylinder, the shrinkage at the inner surface may be made as small as we please, or may be made an expansion. Practically the same result may be obtained by subjecting only a portion of the external surface of the cylinder to pressure. By suitably changing the area subjected to pressure, the shrinkage of the interior may be controlled. This is the method adopted with the present gage. A second feature of the high-pressure gage which minimizes leak is its small size; the diameter of the free piston was $^1/_{16}$ in.

The cylinder and piston are shown in Fig. 3. In Fig. 4 they are shown in place in a large steel block which serves as a reservoir between the gage and the pressure pump. The dimensions of the important parts are indicated in Fig. 3. The thrust on the piston P (Fig. 1) is taken by the large cylindrical rod A joined to the piston by a forced fit. A terminates in a hardened point B, on which the weights are hung by a stirrup supporting the scale pan underneath the large steel block. The upper end of the cylinder acts as a guide for the rod A, as does also the attachment screwed onto the top of the cylinder shown in Fig. 2. It is essential that fitting here should be accurate, so that the small piston may move freely in a vertical line without danger of any bending of the top end when projecting some distance from the cylinder.

Measurement of Pressure—Secondary Gage

Having once reached a standard pressure by the absolute method, any convenient device could be used as secondary. The most suitable method is that based on the change of resistance of a wire under pressure. Manganin wire is the most convenient for that purpose because the temperature effects are very small. Moreover, the electrical resistance of the manganin bears an exact linear relation to the pressure. To secure a standard point of reference I use the freezing pressure of mercury which is 7640 kg. per sq. cm. (as determined by use of the primary gage), and a single such determination is sufficient for calibration. Electrical measurements may be made by the Null method and the Carey-Foster bridge.

Cylinders Ruptured under Internal Pressure

It is interesting to examine some of the specimens which were actually ruptured by internal pressures. The ordinary theory of the bursting or yield of cylinders under internal pressure is well known. At the inner surface the stress is a pressure on planes at right angles to the radius, and a tension on planes including the axis and radius; the corresponding strain is a circumferential elongation and a radial compression. At the inner surface the stress difference, the principal stress, the principal strain, and the strain difference all have their maximum values. On any theory of rupture, then, rupture would be expected to start at the inner surface. The precise value of the theoretical bursting pressure depends on the criterion accepted for rupture. If the principal-stress criterion is accepted, rupture in a thick cylinder will occur when the hydrostatic pressure is equal to the tensile strength; if the maximum elongation is accepted, rupture will occur for a material like bessemer steel at an internal pressure about four-fifths of the tensile strength.

The fact is, however, that for the ordinary materials of engineering practice rupture begins at the outside and runs in toward the center. This rupture may take place either by tearing apart of the metal in an axial plane, or else by slip on a shear plane, the fracture in this latter event running in toward the center approximately as an equiangular spiral.

Most of these bursting tests were made on drawn bars, which were pierced with the hole first and then turned off slightly on the outside so as to be concentric with the hole. Of course the most obvious suggestion with regard to this rupture from the outside is that there were flaws in the outer skin of the drawn bar penetrating more or less deeply into the interior, and that the rupture started from one of these flaws. In order to prove definitely that this is not the case, the following test was made. A bar of bessemer steel $4^1/_2$ in. in diameter was turned down to 4 in. so as to remove the outer layer. From this 4-in. bar a number of rings 4 in. in diameter and $^1/_8$ in. square in section were turned at regular axial intervals of about 1 in. From the bar left after cutting off the rings a cylinder for testing was made in the usual manner about $3^1/_2$ in. in outside diameter, $^1/_2$ in. in internal diameter, and 8 in. long. From the other end of the same bar a similar set of rings and a similar cylinder were turned, only smaller, the cylinder being 2 in. in outside diameter and $^1/_2$ in. in internal diameter. The rings were then tested to rupture on an expanding mandrel. No trace

of flaw in the steel was found; the rings expanded between 10 and 15 per cent before rupture, and the location of the fracture was haphazard, showing no longitudinal vein of special weakness in the steel. The cylinders were then tested to rupture in the usual manner. For this purpose, where the cylinders are made of very ductile material, it was found convenient to fill the cylinders with lead instead of with a true liquid, since it is easier to keep the lead from leaking after the cylinder has begun to stretch. The lead transmits these high pressures nearly hydrostatically. Pressure was produced by a hardened steel piston forced against the lead by the ram of a hydraulic press. A cup-shaped washer of bessemer steel prevented the lead from leaking past the piston. Because of the very great stretching it was necessary to make several strokes of the piston before rupture was produced.

The results of these two tests with the two cylinders mentioned above are shown in the illustrations. The larger cylinder, Fig. 5, broke by the separation of the fibers along an axial plane. Breaking occurred suddenly with an explosive report, so that it was not possible to ascertain whether rupture really started from the outside or not. But with the smaller cylinder, Figs. 6 and 7, breaking started more gradually, and it was possible to watch the whole proceeding. In fact, two strokes of the piston were necessary to enlarge the crack to the condition shown in the figure after the first beginnings of the fissure appeared at the outer surface. The fissure appeared first as a small longitudinal crack, which extended itself axially, the central portion gaping wider and wider as the metal on one side protruded by slipping out along a shear plane.

These two experiments showed that the rupture, which apparently began at the outside, was not produced there by flaws in the steel. There might still be some question as to whether the rupture really did begin at the outside, since of course it is conceivable that the slip had begun at the inside and traveled to the outside, there first becoming noticeable. That the rupture actually does begin at the outside was shown by other experiments on nickel-steel and on copper cylinders. The nickel-steel cylinders do not stretch so much before rupture as the bessemer cylinders, so that it was possible to produce rupture of these cylinders with a true liquid transmitting pressure. That the rupture really begins at the outside was shown by the appearance of the crack on the outside and its gradual growth, just as above, without any liquid leaking through from the inside, as of course it would have done under the high pressure, 30,000 atmos., if there had been the slightest crack reaching from the center out. The copper cylinder showed the same thing. Here it was possible by a special arrangement of shrunk-on steel rings to make the necessary connections and produce rupture with a fluid. Rupture again appeared at the outside first, and spread toward the center along a shear plane, leakage not finally occurring until the crack had opened to the dimensions shown in Fig. 8.

Fig. 5 One of the Halves of a Cylinder of Bessemer Steel (Originally 4 in. in External Diameter) Ruptured by the Application of Internal Pressure. The Inner Hole Has Stretched from $^1/_2$ in. to $1^3/_8$ in.

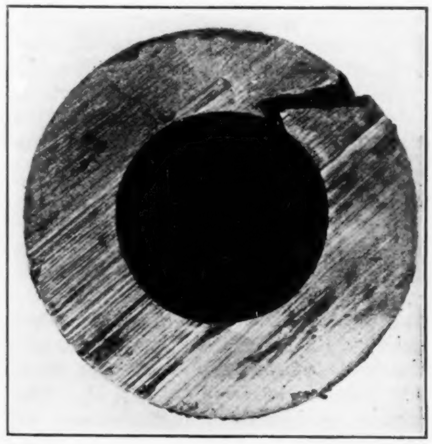


Fig. 6 Cross-Section of a Cylinder of Bessemer Steel Ruptured by the Application of Internal Pressure. This Cylinder was Originally 2 in. Outside and $^1/_2$ in. Inside Diameter. The Inner Hole has been Stretched to $1^3/_8$ in.

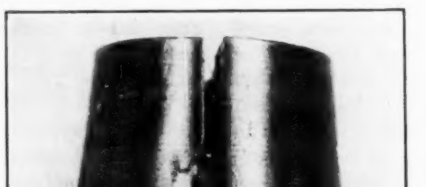


Fig. 7 View of the Outside of the Cylinder of Fig. 6 Taken Before the Section was Made

Fig. 8 Cross-Section of a Copper Cylinder Burst by the Application of Internal Pressure. The Inner Hole Has Been Stretched from $^1/_8$ in. to $^3/_8$ in.

One feature common to all these tests, whether the rupture through the mass of the metal takes the form of a tearing of the fibers or a shear, is that at the inner surface the break is always along a shear plane for a short distance. If the rupture from the outside is by tearing at the inside there are almost invariably two shear planes, running down into the tear. The result is that a sliver of metal in the form of a triangular prism is expelled through the crack. This sliver has been caught on several occasions in a block of lead. It is difficult to see how this shear along two planes could get started if the crack originally started from the inside. Evidently the crack runs in from the outside until so close to the center that the prism slips into the crack, driven by the high internal pressure. This universal manner of rupture affords additional evidence, in those cases where the rupture occurs so suddenly that it cannot be observed, that the crack starts from the outside.

The particular bearing of this type of test on the theories of the conditions of rupture is in showing that the maximum-extension criterion does not hold, although of course all the other criteria are also ruled out if the stress-strain relation is calculated up to the rupture point by the ordinary theory, because every one of the supposed critical quantities has its maximum value at the inner surface. But the striking feature of all the tests is the enormous stretching of the inner surface without rupture. The bessemer-steel cylinders of Figs. 5 and 6 show a circumferential elongation at the inner surface of 175 and 125 per cent, respectively. A tool-steel cylinder stressed had an interior elongation of 120 per cent. The copper cylinder of Fig. 8 shows an interior elongation of 300 per cent, and a lead cylinder showed one of several thousand per cent. There does not seem to be any connection between the

value of elongation at the exterior surface, where rupture actually does occur, and the elongation under pure tensile tests at rupture. We may have values either greater or less than the tensile elongation. The nickel-steel cylinders, those of specially toughened steels, the copper cylinders, and the 3-in. bessemer cylinder all showed a circumferential elongation at rupture very much less than the elongation at rupture under pure tension. The 2-in. bessemer cylinder showed an elongation almost exactly equal to that shown by the rings cut from the same piece, while a drawn tube of annealed steel has shown an elongation of 100 per cent at the outside, and the lead cylinder shows 300 per cent. The tensile value for the steel is about 20 per cent, and for the lead, 25 per cent.

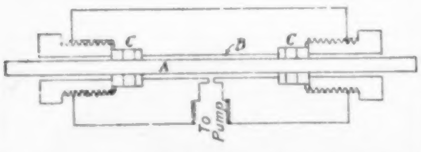


Fig. 9 Apparatus for Producing the "Pinching-Off" Effect, that is, the Separation of the Longitudinal Fibers by the Application of Pressure to the Curved Surface of a Cylinder

(The specimen is shown at A; the fluid exerting the pressure by which the rupture is produced is contained in the annular space at B.)

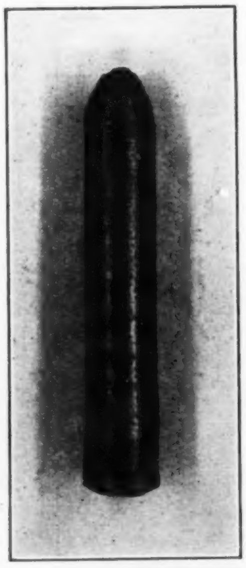


Fig. 10 Photograph of a "Pinched-Off" Specimen, Ruptured in the Apparatus of Fig. 9

Rupture by the "Pinching-Off Effect"

A certain type of test I have made has the most direct bearing on the maximum-tensile-stress criterion of rupture. In these tests cylinders were exposed to pressure over the curved surface only, the ends being left unsupported. Fig. 9 illustrates the manner of applying pressure. The rod A, the subject of the test, passes completely through the cylinder B, projecting at either end through the packing rings C. The cylinder is connected to the pressure pump through the indicated connections and stress applied to the test specimen by the pressure of the fluid in the annular space between the specimen A and the interior wall of the cylinder. The specimen fails by separation of the particles across some plane perpendicular to the axis, the two disconnected ends of the specimen being expelled with violence through the packing rings. The fracture does not take place at the packing rings as might be expected, but, whether for brittle or ductile materials, occurs at some point well between the rings. The nature of the process of rupture is evidently merely that of squeezing the rod out sidewise. This type of rupture may therefore be referred to as the "pinching-off effect." There is no longitudinal stress except that due to the friction of the packing, and this a stress of compression rather than one of tension, so that here we actually have the fibers separating against the direction of stress.

The nature of the fracture varies with the material. In the case of a rod of mild steel, the rupture looks very much like that of an ordinary tensile break, except that the necking down is likely to be a little more abrupt. Fig. 10 shows a photograph of one such specimen. Other soft materials, such as copper or brass, show the same manner of rupture. Harder materials, such as hardened chrome-nickel steel or vanadium steel, show irregular fracture—a combination of necking down and of slip on shear planes at approximately 45 deg. to the axis. Glass-hard tool steel, on the other hand, shows a clean break at right angles to the axis without necking down. In the same way it is possible to break glass rod or heavy glass tubing. The fracture is beautifully clean, exactly at right angles to the axis.

In the cases of the ductile materials the test is complicated somewhat by the fact that after the necking down has once begun there is a tensile stress tending to pull the bar apart. But this tensile stress cannot account for the beginning of the necking down, so that the tensile stress present during the actual rupture is only an incident due to the particular form of experiment, and is not at all the true cause of the rupture. Evidently there is no such complication in the case of the brittle materials which break with no necking down.

This first type of test disposes of the maximum-stress criterion, therefore, as applied to either ductile or brittle materials. It shows a fortiori, therefore, that this criterion cannot be applied to brittle materials in contradistinction to ductile materials.

Furthermore, the yield or set point and the rupture point practically coincide. No cases have ever been observed of a bar receiving set under this type of stress without rupture. The maximum-stress criterion is applicable, then, neither to rupture nor to set.

Incidentally this test disposes also of the maximum-stress-difference hypothesis, although more direct evidence is afforded by another type of test. The principal stresses for this first type of test consist of a compression equal to the hydrostatic pressure on all planes including the axis, and a small compressive stress due to the friction on the plane normal to the axis. The maximum stress difference is equal to the hydrostatic pressure decreased slightly by the amount of friction. In the similar case of a bar ruptured by tension, the maximum stress difference is equal to the tension. If the maximum-stress-difference theory holds, therefore, the "pinching-off effect" should be produced by a hydrostatic pressure equal to the tensile strength in pounds per square inch. As a matter of fact, the stress to produce rupture always exceeded this by 25 or 50 per cent, except for the glass, when the condition was more nearly fulfilled.

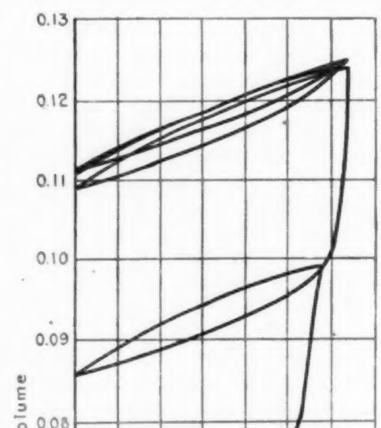


Fig. 11 Diagram Showing the Relation between Internal Volume and Pressure of a Cylinder Strained Beyond the Elastic Limit by the Application of Pressure over the Entire External Surface

Cylinders Subjected to External Pressure

Another type of test very similar to the preceding one is diametrically opposite in its effects. The material for these tests is in the shape of a hollow cylinder, closed at the ends, and subjected to hydrostatic pressure over the entire external surface, on the ends as well as on the curved part of the surface. The tendency of the stress, as is well known, is to collapse the cylinder if the walls are comparatively thin. Such tests are familiar to engineers; the tube folds in on itself in two, three, four, or more creases, depending on the dimensions of the tube originally and on the very slight departure from perfect geometrical symmetry. That there is collapse at all must evidently be due to some slight geometric imperfection. If the tube is made heavier, however, so that geometric irregularities have less effect, the tube does not show collapse by folding under pressure, but shows behavior of a different sort, depending on the material. Tests of this sort do not seem to have been made hitherto, or at

least are not well known, probably because the pressure required to produce the effect is fairly high.

If the material of the cylinder is a ductile metal like mild steel or copper, the effect of the pressure is to close up the hole uniformly, the cylinder retaining its geometric figure. Rupture is never produced in a test of this kind, the hole eventually closing up perfectly tight if the pressure is pushed far enough. This is perhaps as one would expect; the interesting feature of this method of testing is the enormous raising of the elastic limit that it is possible to produce, and the unusual stress-strain relation below the yield point. At one time tests were made simultaneously on seven such hollow steel cylinders. The upper ends of these cylinders were led out of the pressure chamber and connected to graduated glass capillaries. The interiors of the cylinders were filled with mercury, so that by observing the rise of mercury in the capillary it was possible to follow the change of internal volume with pressure. No change of length accompanies the closing of the hole, so that the rise of mercury in the capillary gives directly the change of internal volume with pressure. Fig. 11 shows a typical diagram of the test for one cylinder. Pressure was successively applied and removed, each maximum being greater than the preceding maximum. The diagram shows distinctly the location of the yield point, and shows also that with every application of pressure the new yield point is not reached until the previous maximum has been passed. This of course is only a verification of common experience as to the possibility of hardening by overstrain. But former experiments on hardening by overstrain have usually been with tensile or compressive or torsion tests, where the possible raising of the yield point is restricted in amount, a rise of 50 per cent being large. Hence in these collapsing tests the possible raising of the yield point seems to have no limit except that set by the complete closing up of the hole. In the diagram just referred to above, the yield point has been raised about six-fold; in similar tests with copper, where the process has been followed to complete closing of the hole, the yield point has been raised ten-fold, from 1000 to 10,000 atmos. This was unexpected; one might naturally expect a raising of the yield point to two or three times the original value, but after this the metal might be expected to flow uniformly toward the center like any viscous fluid.

The experiments with copper also showed the manner in which the yield point is connected with flow. The maximum pressure reached in any cycle, plotted against the internal diameter, gave a nearly straight line extending from the original diameter at zero pressure to zero diameter at 10,000 atmos. That is, for equal increments of the yield point the diameter decreases by equal amounts. One might expect perhaps that the diameter would tend to decrease more rapidly at the higher pressures. The material of the cylinders after these tests remained perfectly homogeneous, without fault of any kind. Microscopic analysis has failed to reveal anything of interest except a slight elongation of the grains in the direction of flow.

The diagram shows interestingly one other variation in the normal behavior of metal under high pressure, which is mentioned because of its intrinsic interest, although the bearing on theories of rupture is not so immediate. This is the unusually large hysteresis which goes with the raising of the yield point. The mere existence of hysteresis as an effect apart from "elastische Nachwirkung" has even been questioned by some. A diagram like the present shows unmistakably the possibility of this effect entirely apart from any elastic after-effects. It also suggests that the hysteresis may in some way be connected with an unstable configuration of the molecules set up in the metal by the overstrain. In the case of ordinary metals, where hysteresis appears before the yield point of the metal as a whole has been reached, hysteresis is probably connected with local yield in the neighborhood of the larger or more unstable crystalline complexes of the metal.

The application of all this to theories of rupture is immediate. It suggests, in the first place, that there is no necessary connection between the yield point and the rupture point. Engineers, after some discussion, seem to have accepted the yield point as the best criterion of rupture. The reason seems to be that the yield point and the rupture point are fairly close together, the yield point is pretty definitely located, and it is possible to calculate the relation between stress and strain up to the yield point and so to find a criterion at least for yield, if any exists; whereas it is well known that the usual relations between stress and strain break down in the regions of viscous flow between the yields and the rupture points. Here, in these tests, there is a yield point but no rupture point at all, so that certainly, even if a criterion were found for yield, it could not be extended to rupture.

These tests further show that the maximum-stress-difference criterion of yield is no more valid than the maximum-stress-difference criterion of rupture. For if the distribution of stress in the cylinder be calculated on the maximum-stress-difference hypothesis, it will be found that the hole in the cylinder will never close up under any pressure, no matter how large. The mathematical solution of this problem I have given in another paper in which this whole question of the collapsing of cylinders is taken up much more in detail. The solution assumes that the maximum-stress-difference condition holds throughout the entire extended process of yield. To account for the observed complete closing of the hole it is necessary that the greatest stress difference which the metal can support become less in the last stages of yield. To inquire whether the initial yield always occurs at a definite stress difference would be of little avail, for it is well known that even for the ordinary tests of engineering the material must first be put into a state of ease by subjecting it to considerable stress. If it is not so subjected to preliminary stress, it may show yield or departure from Hooke's law at values of the stress very much lower than normal. But in tests of this type there is no natural limit to the stress which shall be used to put the cylinder in a state of ease, and since the diagram shows plainly that the beginning of yield is not sharply defined, there is here no possibility of a natural initial yield point to which a criterion might be applied.

So far this collapsing test has been discussed only in its application to ductile materials, like copper or steel. The behavior of a brittle material like glass under the same conditions is strikingly different. Cylinders of glass made of heavy capillary tubing sealed at both ends, and hollow spheres with thick walls, have been subjected to hydrostatic pressure up to 24,000 atmos. No permanent measurable change is produced, there being neither crushing nor alteration in the dimensions of measurable amount. It should be said, however, that there must be some slight amount of flow and of interior adjustment to the pressure, although too small to measure, because several of the glass cylinders have broken spontaneously several weeks or even months after the release of pressure. Others have been kept without fracture for a couple of years. One would expect that under the conditions of this test the glass would be crushed. This is the case if the cylinder has not been carefully annealed or if it is geometrically imperfect; the material may then be reduced to an almost impalpable powder. This complete destruction of the minutest fragments of the glass apparently is because the wave of expansion, traveling through the mass after the break has started, at any point is of such intensity that every minute portion is reduced to powder by its own inertia.

For a brittle substance like glass, which shows no flow, we may calculate the distribution of stress by the ordinary theory of elasticity. It is thus found that the maximum stress difference will occur at the inner surface of the cylinder, and for a thick cylinder will be equal in amount to the external hydrostatic pressure. We have already seen that if the maximum-stress-difference criterion were valid, the greatest stress difference that the material could support would be equal to its tensile strength. Therefore, since the tensile strength of glass is seldom as high as 7000 lb. per sq. in., we should have had crushing under the conditions of the test at a hydrostatic pressure no higher than 7000 lb. per sq. in. if the maximum-stress-difference theory were valid for brittle substances. But fifty times this value has been reached without rupture.

These experiments bring out strikingly the difference between a crystalline and an amorphous material. The glass is truly amorphous and isotropic down to molecular dimensions: such flow as would cause the cylinder to collapse cannot occur, although the ordinary elastic limit is very much exceeded because such flow would involve a differential yielding of one part at the expense of another, and all the parts are equal. In the metal, on the other hand, the small-scale structure consists of crystalline grains in each one of which there are planes of easiest deformation. Collapse of a hollow steel cylinder occurs by slipping within the grains on the slip planes.

These collapsing experiments also dispose of one other criterion of yield or rupture. This is the third criterion mentioned above, namely, that rupture or yield will occur when the extension in any direction exceeds a critical value. If the strain is calculated in a cylinder exposed to hydrostatic pressure over the outside, the radial strain is found to be an extension at the inner surface. In the case of the ductile materials which flow toward the center, this radial extension increases enormously with increasing flow, always without rupture or separation of the fibers in the direction of elongation. And in the case of glass under 24,000 atmos., where there is neither rupture nor flow, the elongation at the center is greatly in excess of the elongation at rupture in an ordinary tensile test, and therefore in excess of the supposed critical elongation.

Another type of test shows most convincingly the failure of some of the ordinary criteria of rupture. If a hard-rubber ring is fitted snugly over a steel core and the ring and core are together subjected to hydrostatic pressure in a liquid in which they are immersed, it will be found that at a high enough pressure the ring is split just as it would be under ordinary conditions by expanding it by driving into it a conical core. Here we have rupture of a material in which every fiber is shortened and every stress is compressive.

Finally, it should be possible to use these tests in a more constructive way by building up with their aid some criterion of rupture which should be valid under all conditions. This I have not attempted to do. It is possible, however, to state one feature in which such a universal criterion will differ from the usual partial criteria. To the ordinary mechanical conditions there must be added some condition of a purely geometrical character, for it is obvious that rupture cannot occur unless there is some place for the fragments to go such that the stress will thereby be relieved. It is some condition of this kind which makes a heavy cylinder break on the outside under internal pressure, and which makes it

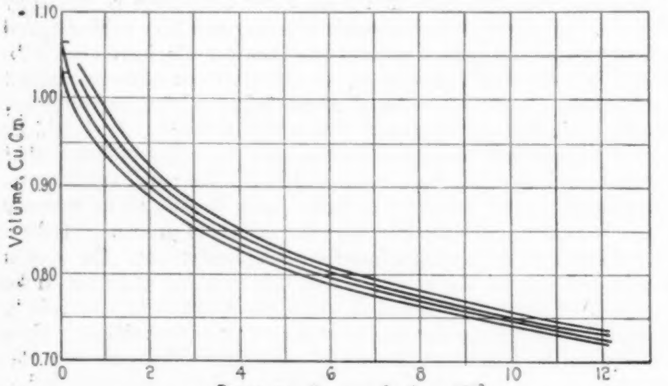


FIG. 12 COMPRESSIBILITY OF WATER UNDER PRESSURE

impossible to collapse a hollow sphere or cylinder of glass by a pressure many-fold the anticipated value.

ACTION OF MERCURY AND GASES ON STEEL AT HIGH PRESSURES

Another effect connected with the rupture of these cylinders is the effect shown when I filled the cylinder with mercury and tried to transmit pressure by means of that. No cylinder of steel will stand a pressure of more than 100,000 lb. per sq. in., when exerted by mercury. If you put on more pressure than that, the mercury comes out through the pores of the steel. The action is something like amalgamation; the amalgamation is helped by the action of the pressure itself because the pressure distends the pores and forces mercury in. The atom of mercury is very small, and so finds it easy to get in between the atoms of iron; you cannot squeeze liquids like ether which have a comparatively large molecule through any container.

Gaseous hydrogen is much like mercury in its action. At room temperatures hydrogen under a pressure of 9000 atmos. will penetrate the walls of a steel cylinder of any thickness. The action is instantaneous, and the escape of the hydrogen is explosive in its violence: the hole through which the hydrogen escapes may be so small as almost to defy detection. It is not unlikely that other highly compressed gases, such as air, are similar in their action, although very much slower.

Now to go on to subjects of more physical interest. I will speak briefly of the magnitude of the changes of volume.

CHANGES IN LIQUID VOLUME UNDER PRESSURE

There are many stories in circulation about the pressure at the bottom of the ocean at six miles of depth. This is only equal to 15,000 lb. per sq. in., but it is higher than ordinary practice and there are fabulous stories as to its effects. These stories are of two kinds. In one kind of story the water of the sea becomes so dense under these pressures that no steel ship will sink to a depth greater than two or three miles, where it floats in water which has there acquired the density of the steel. That is not true.

The other kind of story grows out of the veneration for the incompressibility of water. That rests on a curious error. Mr. Perkins, an American who lived in the neighborhood of Boston, published in the Proceedings of the Royal Society of London an article with this title: "An Experiment to Prove Water is not Incompressible." It was misprinted in the index as, "Water is Incompressible," and it has been quoted in that way ever since. You are also told that if you lower a hermetically sealed steel vessel into the

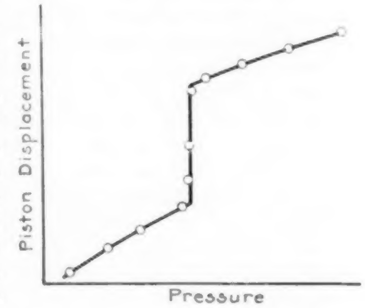


FIG. 13 DIAGRAM SHOWING THE SHARP CHANGE OF VOLUME DURING FREEZING

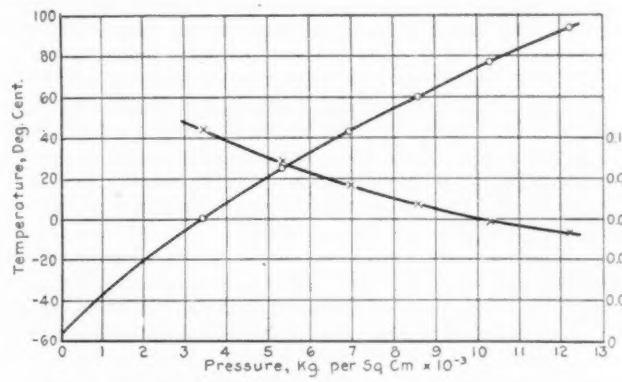


FIG. 14 MELTING POINT OF CARBON DIOXIDE

depths of the sea the water is forced through the pores and gets inside.

The actual changes of volume produced by these pressures are between these two extremes. An ordinary liquid under pressure of 200,000 lb. per sq. in. loses in volume about thirty-three per cent. In Fig. 12 I have plotted the volume as a function of pressure. At about 180,000 lb. per sq. in. the volume drops off 30 per cent from its original value. It is curious that most organic liquids show about the same decrease of volume. The interest of this change of volume is that it points to an actual compression of the molecule itself, which is not evident in low-pressure phenomena. These liquids are perfectly elastic. When you take the pressure off, the volume comes back to its initial value. Another interesting property of liquids under high pressure is the amount of work that can be stored up in a liquid by compression. It turns out that a great deal more work can be stored in gas at moderate pressures than in a liquid at high pressure. This tends to make high-pressure experimentation with a liquid safe. Another factor which makes experimentation safe is that the volumes and masses of liquid are so much smaller than the masses of steel used to contain the liquid. If you figure out how much work you can put into ether, you will find that at 12,000 atmos. you cannot get in more than enough energy to raise it to a height of 60,000 ft. That sounds like a great deal, but it is not much compared to the energy that can be put into a gas.

EFFECT OF HIGH PRESSURE ON MELTING POINT

The next topic I have to take up is the effect of pressure on the

melting point. This is of some remote interest to engineers because you are all interested in the corresponding problem for the liquid and the vapor state. There you are familiar with the fact that there is a critical state where liquid and vapor merge and where they lose their distinction. The question is whether you have the same relation for liquid and solid vapors. Different theories have been set up, none of which have turned out to be right. The whole question is an experimental one. High pressures are needed to settle it, pressures that we now have available. In experiments dealing with the effect of high pressure on melting point it is necessary to coördinate changes in volume with pressure. The volume in my tests was given simply by the position of the piston of the compressor, the piston being leakproof. In Fig. 13 the position of the piston is plotted against the pressure. This particular curve is for the melting of ice. At the break in the curve the ice froze and the piston dropped into the cylinder with no rise of pressure. The position of the discontinuity indicates the pressure at which the water froze, and the magnitude of the discontinuity gives the actual change of volume.

Fig. 14 shows the melting curve of carbon dioxide, the temperature of melting being plotted against pressure. This curve is of interest because it rises indefinitely with no discontinuity of any kind, and gives no suggestion whatever that 30 deg. cent. is the critical point between liquid and vapor. There is no connection between the relation of the solid and the liquid and the relation of liquid and vapor. It is possible to start at atmospheric pressure at a temperature above the critical temperature and compress the vapor without discontinuity of any kind, until a pressure so high is reached that the *vapor* is compelled to condense directly to the solid.

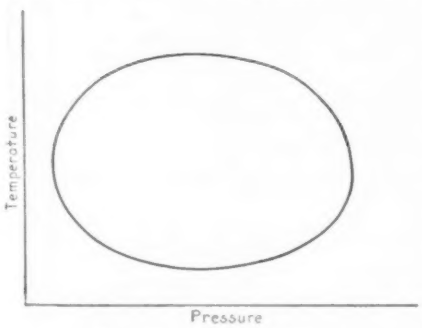


Fig. 15 Tammann's Egg

Theories of Melting

I am not going into the various theories of this, but there was one theory which was favored before I took up this work and that was the theory of Tammann. Fig. 15 shows what was known as "Tammann's Egg." Inside the egg the material is solid. If the pressure is raised at constant temperature, the material is first forced to freeze, and then is forced to unfreeze by putting on more pressure. This theory can now be absolutely ruled out. I have plotted Fig. 16 to illustrate my argument. If Tammann's Egg represented the facts, these curves would be concave downward instead of upward.

These curves also give a proof that there is no critical point between liquid and solid like that between liquid and vapor. The facts seem to be that by applying enough pressure to any liquid you can force it to freeze. The amount of pressure per degree rise of the melting point you have to apply increases with temperature, but the curve does not become flat and, as far as I can tell, continues to rise indefinitely.

Properties of Water under Pressure

The next topic I have to discuss is the properties of water under pressure. I have chosen water because it is so familiar to all of us that I thought the facts might be of some interest. In the first place, water is anomalous. It expands when it freezes. That means that the freezing point is depressed when the pressure is raised.

In Fig. 17 are the pressures in kilograms per square centimeter and the corresponding freezing temperatures of water. For instance, at −10 deg. cent. you can force the ice to melt by applying between eleven and twelve hundred atmospheres. Before I go on to how ice behaves under higher pressures, I would like to stop and show you how liquid water behaves.

In Fig. 18 I have plotted temperature and volume of water at a series of constant pressures. The top curve shows volume under atmospheric pressure. From + 4 down to −10 deg. cent. the volume keeps on increasing. At 500 atmos. you see the same thing, but the temperature of the minimum volume has become less. At 1000 atmos. the minimum comes over still further, and beyond the minimum a point of inflection has appeared. At 1500 atmos. a maximum has appeared beyond the minimum, so that the abnormal behavior is confined to a narrow range of temperature. Maximum and minimum points disappear and the abnormalities of liquid water are wiped out. So that if you put on enough pressure you make water a normal substance instead of an abnormal one.

In Fig. 19 I have plotted the change of volume at melting against the melting temperature. Going up on this curve corresponds to going to higher pressures and lower temperatures. The abnormal

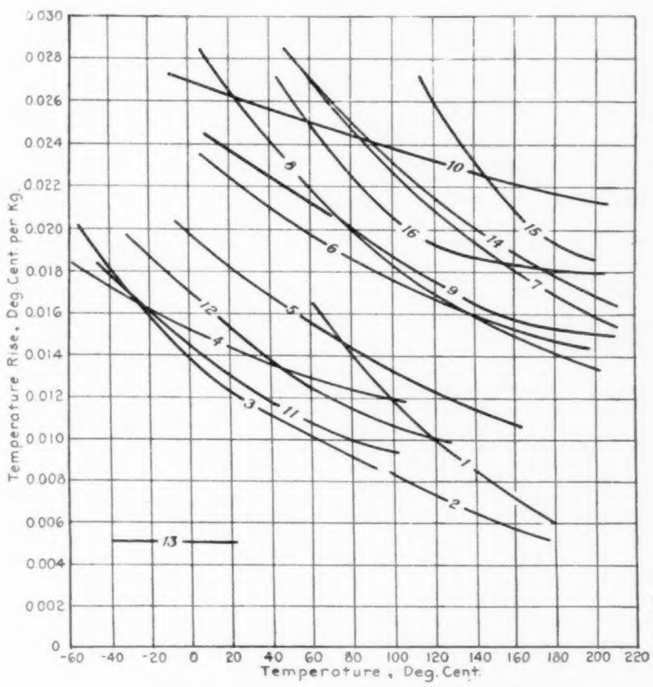


Fig. 16 Curves in Disproof of Theory of Tammann's Egg

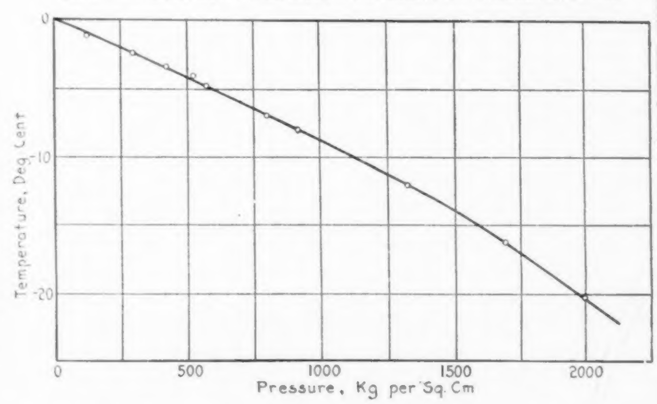


Fig. 17 Freezing Curve of Ice; Freezing Temperature is Plotted Against Pressure in Kg. per Sq. Cm.

difference of volume becomes more and more accentuated as temperatures go down; a difference of volume of 9 per cent at 0 deg. cent. changes to $13^1/_2$ per cent at −22 deg. cent.

Not only is liquid water abnormal, but solid water, or ordinary ice, is abnormal also. We have seen that the abnormalities in liquid water may be made to disappear under high pressure. Analogously, the abnormalities in solid water also disappear under high pressure. However, the manner in which the abnormalities are wiped out is quite different in the case of the solid from the case of the liquid. Ordinary ice is crystalline, and its molecules are piled in some regular way; the abnormality consists in some unusual feature of the method of piling. Pressure wipes out the abnormality by piling the molecules in some more normal way, that is, by changing the crystalline form of ice. There are various stages in the return of solid water to complete normalcy, and in all the existence of five different crystalline modifications has now been demonstrated.

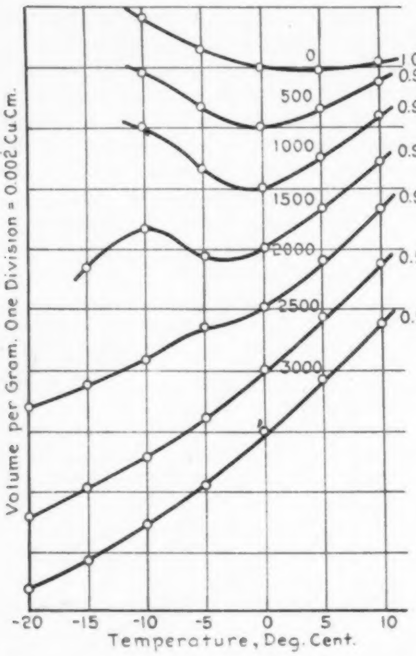


Fig. 18 Curves Showing Relation between Volume and Temperature of Water for Various Constant Pressures

(The numbers in the body of the diagram show the constant pressure of each curve; the numbers at the right show the volume at 0 deg. of the liquid at the indicated pressure. If drawn to scale the curves should be separated about ten times as much as shown.)

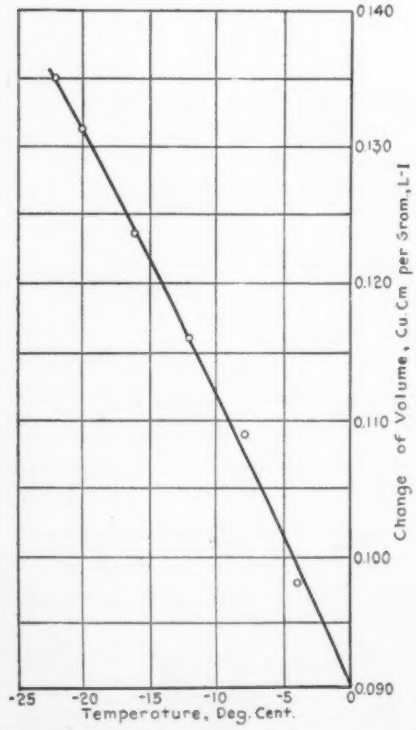


Fig. 19 Change of Volume when Ice "I" Melts to the Liquid

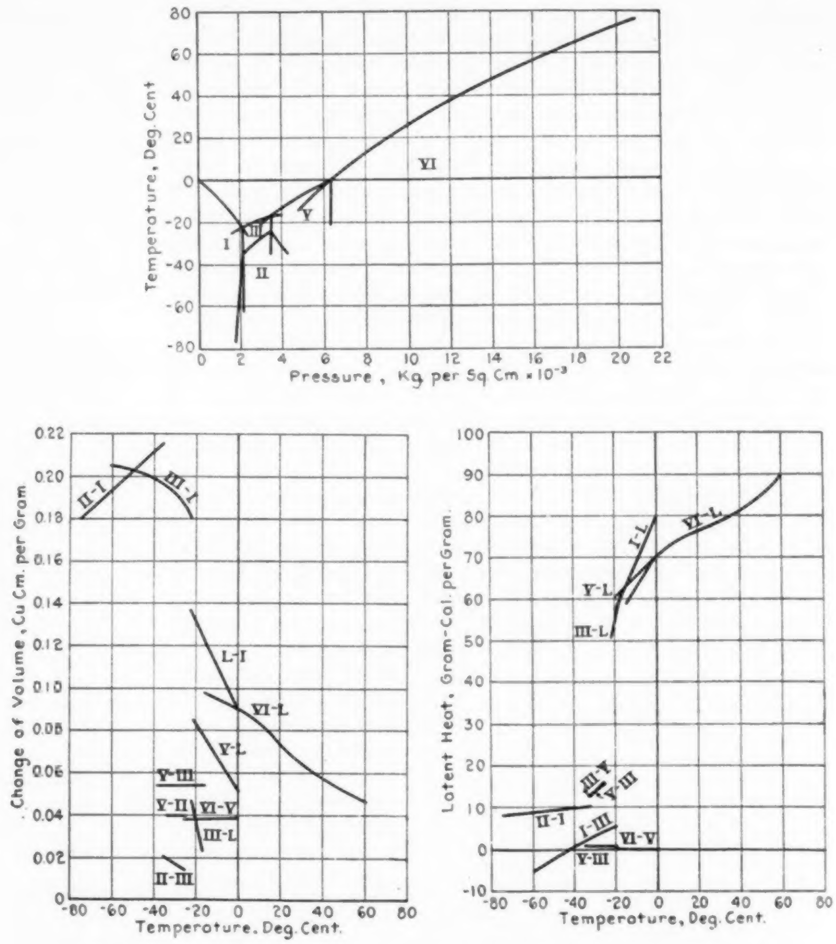


Fig. 20 Behavior of Water in its Liquid and its Five Solid Forms

Above: Equilibrium diagram between the liquid and the five solid modifications of water.
Below, left: Change of volume when one modification passes to another under equilibrium conditions.
Below, right: Latent heat when one modification passes to another under equilibrium conditions.

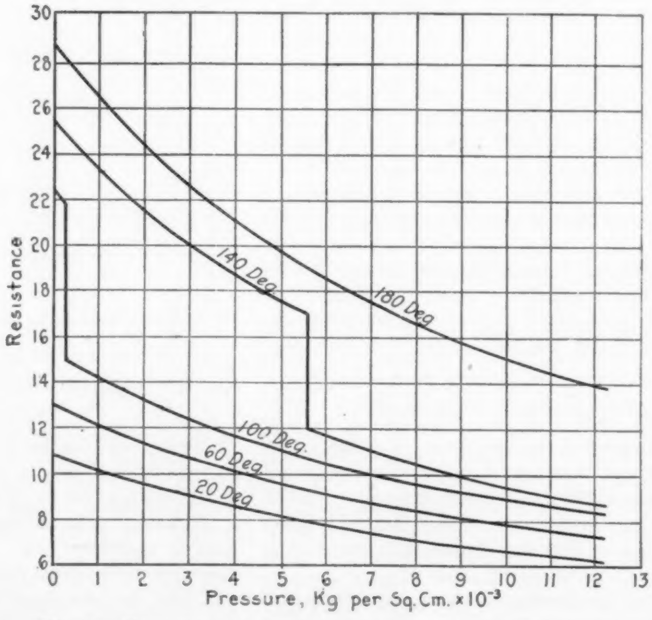


Fig. 21 Electrical Resistance of Sodium Under Pressure

Fig. 20 illustrates the behavior of water in its liquid and its five solid forms in a comprehensive manner. To prevent confusion it should be briefly stated that there are identical relations which must be satisfied in every such diagram. There are three of these relations. At every triple point the relative positions of the three equilibrium curves must be such that if any one is produced into the region of instability it shall fall within the angle made by the other two. If one phase is carried into another by passing across an equilibrium line at constant pressure from a low to a high temperature, then the reaction runs with absorption of heat. And if one phase is carried into another by passing across an equilibrium line at constant temperature from a low to a high pressure, the reaction runs with decrease of volume. In the upper chart of Fig. 20 is given the freezing pressure at any given temperature, and in the lower left-hand chart the freezing temperature is related to the change in volume. The third chart is deducible by calculations based on Clapeyron's equation. A very special technique of experimentation was built up to secure passage from one modification to another, and made necessary measurements at the equilibrium points. Sign convention must be carefully used in interpreting the curves. A change of volume is taken as positive if the volume increases when the reaction runs in the indicated direction. Thus ΔV L-I is positive (water expands when it freezes to ordinary ice) but ΔV I-L is negative. Similarly the latent heat, ΔH, is positive when heat is absorbed during the reaction, and ΔE, the change of internal energy, is positive when

the internal energy increases. It is only possible, in this lecture, to follow one series of modifications very briefly. Thus when water freezes at 0 deg. cent. it increases in volume. If it is compelled to freeze below 0 deg. cent. by increasing the pressure, the increase in volume at freezing increases likewise. This is shown by curve L-I in the lower left-hand chart of Fig. 20, and curve I along the line from 0 deg. cent. At −22 deg. cent. the whole structure of ordinary ice becomes unstable and collapses. It is in-

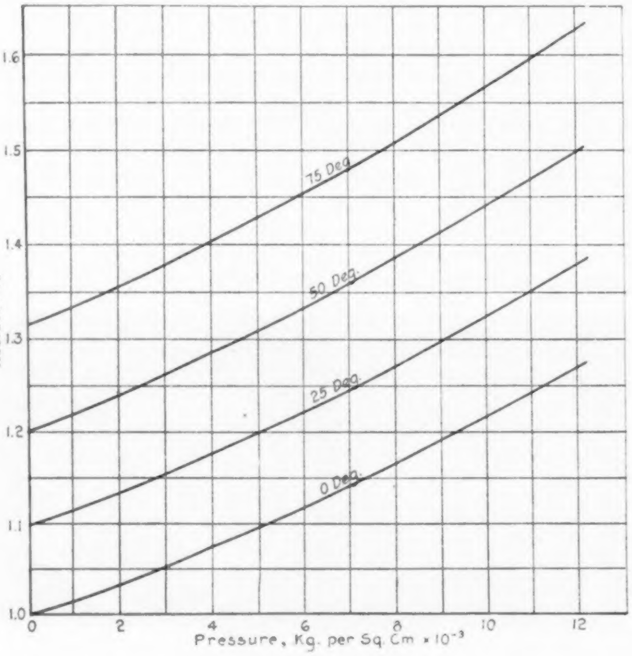


FIG. 22 ELECTRICAL RESISTANCE OF BISMUTH UNDER PRESSURE

capable of existence and flops, with large decrease of volume, to a new modification of ice, with a new crystal form which is denoted by III. The reaction takes place with extraordinary rapidity. As a consequence of the existence of III, it is never possible to generate a pressure greater than 30,000 lb. by freezing water in a closed vessel. If the pressure is increased further another modification is formed. Finally, when temperature is by a strange coincidence in the region of the ordinary melting point of ice, still another modification, V, is obtained, which is maintained indefinitely as "hot ice" with increasing temperatures and pressures. This form may be even maintained up to the boiling point of water. These few remarks will indicate at least what a fascinating field has been opened up in the study of these various forms of solid water.

ELECTRICAL RESISTANCE OF METALS UNDER PRESSURE

I now have two more topics which I will speak of very briefly; one is the electrical resistance of metals under pressure. You are already acquainted with the fact that the electrical resistance changes. The resistance of a soft metal like potassium decreases to one-seventh its normal value under a pressure of 12,000 atmos.; if the metal is hard, the decrease in resistance is of the order of a few per cent instead of the order of 70 per cent.

Fig. 21 shows curves connecting the pressure and electrical resistance of sodium at various temperatures. The discontinuities in the curves occur where liquid sodium is forced by the pressure to freeze. I do not know of any one who has proposed that we should fill conduits with sodium under pressure and obtain superconductors. It would be an interesting thing to do, but it is not possible.

In Fig. 22 we have another type of behavior, that of bismuth. Not only does the resistance increase under pressure, but all the curves are concave upward; the more pressure you put on the greater the effect of each equal increment. That is quite abnormal and points to some instability in the structure of bismuth itself. I hope some day to put enough pressure on it to make it collapse, but that has not yet been done.

THERMAL CONDUCTIVITY UNDER PRESSURE

In Fig. 23 we have the thermal conductivity of petroleum ether related to pressure. You see that we may have an increase of thermal conductivity of three-fold accompanying a decrease of volume of about 30 per cent. There is apparently some connection with the velocity of sound in the liquid, because it is possible to calculate from the compressibility of the liquid the velocity of sound, and it turns out that the increase of thermal conductivity runs closely parallel with the increased velocity of sound.

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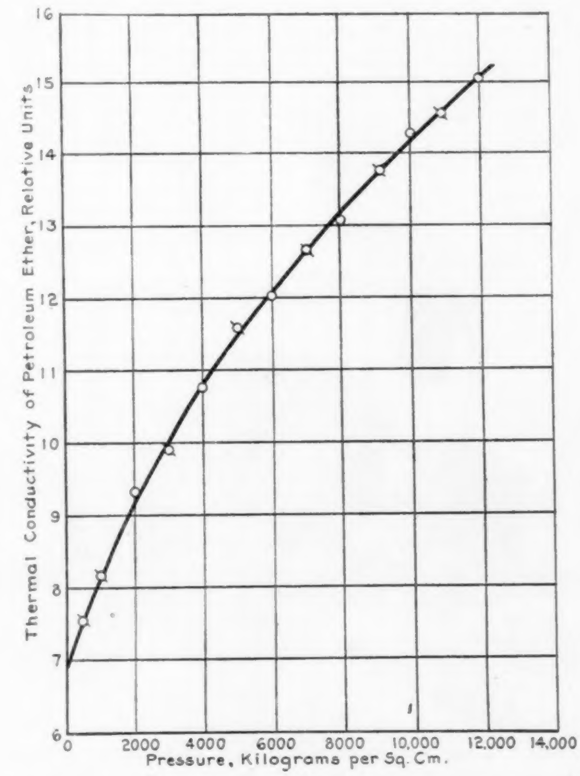

FIG. 23 THERMAL CONDUCTIVITY OF SODIUM UNDER PRESSURE

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Equipment Used for Aerial Surveying[1]

A Description of the Various Types of Cameras and Auxiliary Equipment Employed in Aerial Mapping

By ERNEST ROBINSON,[2] NEW YORK, N. Y.

FROM a military point of view, Government engineers assigned to making aerial maps for military purposes have since the war given continuous study to the importance of developing apparatus that embodies all the mechanical, optical, and electrical refinements together with the absolute reliability of operation expected of field apparatus used in time of war. For obvious reasons it has been the aim of manufacturers of aerial-surveying equipment to design all devices as fully automatic as possible, eliminating the human element on account of the value, expense, and tremendous risk in the operation of surveying an enemy territory from the air.

In times of peace, aerial mapping is done in a two-seater airplane having a square fuselage, the type of plane used by the Army being a DH-4B, the pilot located in the front seat, the camera and operator in the rear as shown in Fig. 1. Three circular holes are cut in the bottom of the fuselage, about nine inches in diameter. One hole is for the pilot's observation in holding his line of flight so that he can more accurately fly over objects or landmarks to provide for proper overlap by sighting to a more true vertical instead of looking over the side of the fuselage, which latter has a tendency to tilt the plane, no matter how careful the controls are handled. The other two holes are in the rear cockpit where the camera apparatus is located—one to provide clear angular vision for the camera, the other to accommodate the vertical view finder which picks up the

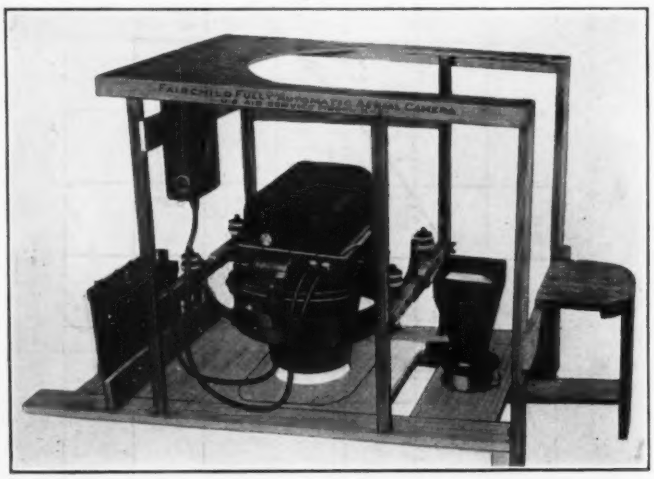

Fig. 1 Showing Location of Aerial Mapping Camera in Airplane

ground area very clearly on a ground glass. This view finder is mounted in a ball socket so that it can be instantly adjusted for level in any direction, and is located directly in front of the operator's seat.

The ground glass, which is nine inches square, is ruled with a series of rectangular lines calculated for the different focal lengths of the camera used, the scale to which the map is to be made (which governs the altitude), and also the amount of overlap, which determines the interval of time between the exposures, which must also be proportioned by the ground speed.

The automatic camera apparatus (a description of which will be given later) consists of an electromechanical device made entirely of metal, a time control, a 12-volt battery, and a double gimbal mount supported by a sponge-rubber clamp to eliminate vibration. All this apparatus is set up in the rear cockpit tandem fashion, the view finder being nearest the operator, the camera in its mount directly in front of the view finder, and the time control ahead of the camera, farthest away from the operator but at a convenient distance for him to set it at the desired interval.

The time control when set at any given interval automatically sets in motion the entire electrical and mechanical cycle of movements of the camera apparatus. If the time control is set at, say, a 15-sec. interval, the camera will operate continuously for 110 exposures. Any number of exposures can be taken up to this limit.

The magazine unit of possibly the most modern aerial camera—known as the K-3—holds a roll of film approximately $9^1/_4$ in. wide by 75 ft. long, and takes exposures 7 in. by 9 in. When large areas are mapped, it is necessary to take several loaded magazines on the flight. The camera body and magazine are designed so that the magazine can be changed in from 3 to 5 sec. This feature provides for continuous mapping under practically all conditions; the interval between exposures is scarcely ever less than 10 sec. The used magazine can be replaced with a new one in not more than 5 sec.,

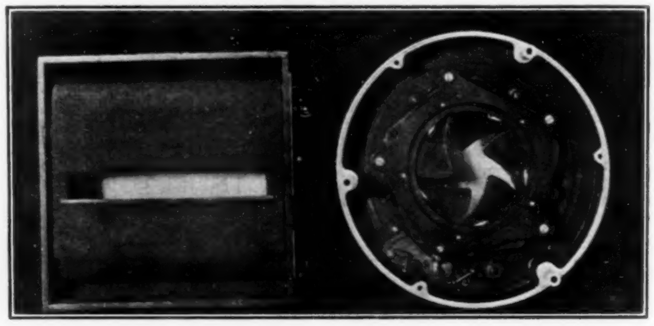

Fig. 2 Comparison of the "Between-the-Lens" Shutter and the Usual Type of Focal-Plane Shutter

therefore continuous exposures can be made without any gaps. This feature is very important in mapping large areas that take more than one roll of film, as perfect photographic days only average one a week, and it is not unusual for a flying field to be 50 miles or more from the area to be mapped.

Types of Airplanes Used

In time of war the performance of the plane and the weight carried is a most important factor, in which case the surveying apparatus is mounted in a scout plane (one-seater), eliminating the photographer. The time control is located on the pilot's instrument board or other convenient place in the pilot's cockpit; the camera is set and clamped level before leaving the ground. When the desired altitude is reached over the area of importance, the pilot simply sets the time control at a given interval figured for approximate overlap by his knowledge of ground speed under the existing weather conditions. The camera apparatus is immediately set in motion and will make any number of successive exposures automatically up to 110. One roll of film in the K-3 camera magazine will cover an area of approximately 2 miles wide by 80 miles long at an altitude of about 15,000 ft. and at a scale of approximately 1200 ft. to the inch. The amount of detail shown in addition to the ability to plot off distances for reconnaissance purposes is, of course, very valuable.

The types of airplanes which have proven most practicable for commercial surveying are the Huff Daland equipped with a Wright E-4 motor and specially designed fuselage, and the Fokker type equipped with a B.M.W. motor. Unfortunately, up to the present very few of the stock-type airplanes embody the combination design to accommodate aerial-surveying apparatus and also the performance required: namely, slow landing, high rate of climb, high ceiling, cruising speed and steadiness to reduce tilt to a minimum, with power enough to hold a ceiling up to 16,000 ft. with a small amount of vibration.

The Fokker plane arranged for installation of either the K-3 or K-1 military photographic apparatus has a 165-hp. (European rating) B.M.W. motor, a speed of 117 miles per hr., rate of climb

[1] Contributed by the Aeronautic Division and presented at the Annual Meeting, New York, Dec. 1 to 4, 1924, of The American Society of Mechanical Engineers. All papers are subject to revision.

[2] Vice-Pres. Fairchild Aerial Camera Corp. Mem. A.S.M.E.

about 900 ft. per min. with full load of approximately 500 lb., 6 hr. fuel supply, and a ceiling of about 22,000 ft.

The Huff Daland aerial surveying plane has a 190-hp. E-4 Wright motor, speed of 105 miles per hr., rate of climb 900 ft. per min. with full load, 6 hr. fuel supply, and a ceiling of about 18,000 ft.

These two planes have been in continual service for the past year and have given satisfactory results. These two particular types are mentioned as they were selected after a careful study of detailed design as applied to the accommodation of installing the surveying apparatus above mentioned. There are, of course, other makes of planes that have equal or better performance, but lack some of the requirements necessary for aerial survey work.

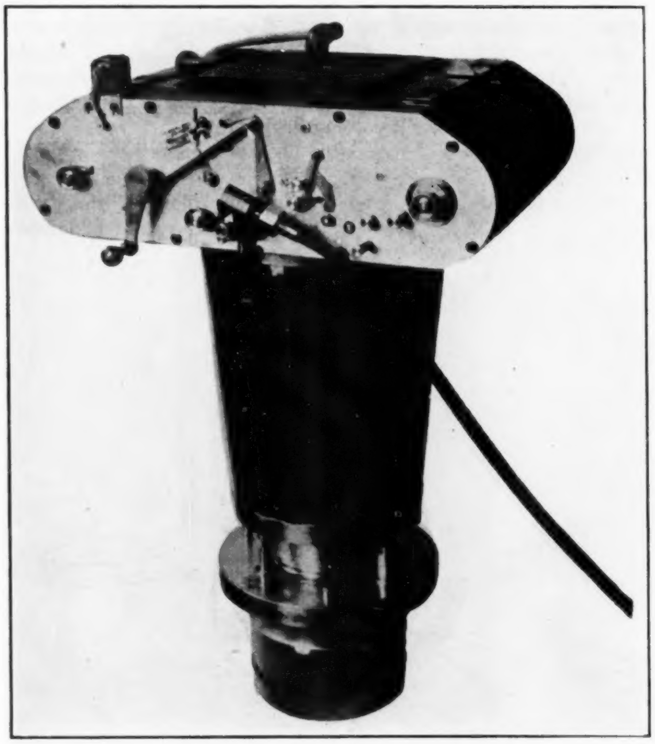

Fig. 3 Model K-1 Wind Camera

The K-3 and K-1 Cameras

The two leading types of cameras used in this country are what are known as the K-3 and K-1. Both cameras are fully automatic and have been given the above titles by the U. S. Government Air Service. The K-3 is perhaps the most modern. It is built entirely of metal, the greater part of which is duralumin, with machine precision throughout, every component part being interchangeable. It is so designed that it can be operated either fully automatically, semi-automatically, or manually at will of the operator without the removal of any part or the adding of any additional parts.

The camera proper, magazine, driving motor, and gimbal mount form a self-contained unit. The time control and battery are the only separate units, the reason for this being that the battery can be put anywhere in the fuselage remote from the camera and the time control can be placed either in the front or rear cockpit; it is just a matter of the length of cable used.

One of the most important features of this camera, or to give it a more appropriate name, aerial surveying machine, is the "between-the-lens" shutter shown in Fig. 2. This is made in two sizes: 30 and 50 cm. or 12 and 20 in. focal length, having an aperture or shutter opening of 2.624 and 3.940, respectively. A shutter of this type has long been considered most desirable for aerial work, but to the author's knowledge it is the first and only design working successfully and replaces the curtain or focal-plane shutter which has given considerable trouble when operating at high altitudes where it is not unusual to run into a temperature as low as 10 to 20 degrees below zero. This "between-the-lens" shutter has been a very hard mechanical problem to solve. It took nearly three years of continual experimenting before the final model passed a successful test made by the U. S. Army Air Service, McCook Field, Dayton, Ohio. In the breakdown tests both the 12- and 20-in. shutters of this type stood up for 40,000 exposures before a weak spot developed.

Up to the present this camera and accessories have not been sold commercially principally on account of the high cost of manufacture and the limited field. About 150 of these equipments have been made, and are in constant use by the U. S. Army, U. S. Navy, as well as the Canadian and Brazilian Governments.

The other important type in this field is the K-1 shown in Fig. 3, which is mounted in the fuselage in the same manner as the K-3. This camera is also automatic in action. The driving power is provided by a wind motor containing a rotary paddle wheel mounted outboard with the control lever accessible to the pilot or observer.

The interval between exposures is set by the operator. Any number of consecutive exposures up to 110 may be made. The same film is used in both types of cameras and is made by the Eastman Company, being what is known as "hypersensitized." This film is very fast and gives splendid results for aerial survey work. The film is held flat at the recording plane by constant vacuum suction created by a venturi tube. The shutter which is of the focal plane of curtain type has a range of exposures from $^1/_{90}$ to $^1/_{310}$ of a second. The total weight of both the K-3 and K-1 is about 50 lb.

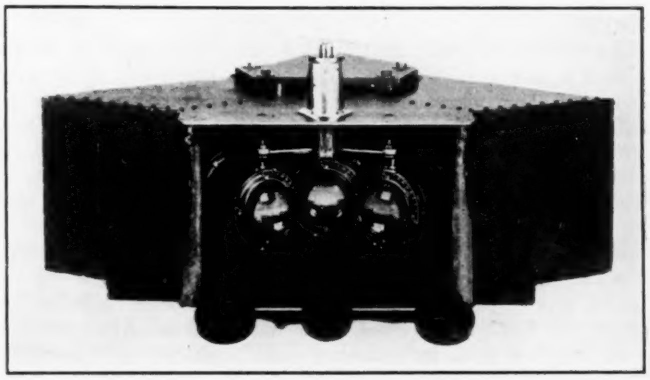

Fig. 4 Front View of Tri-Lens Camera

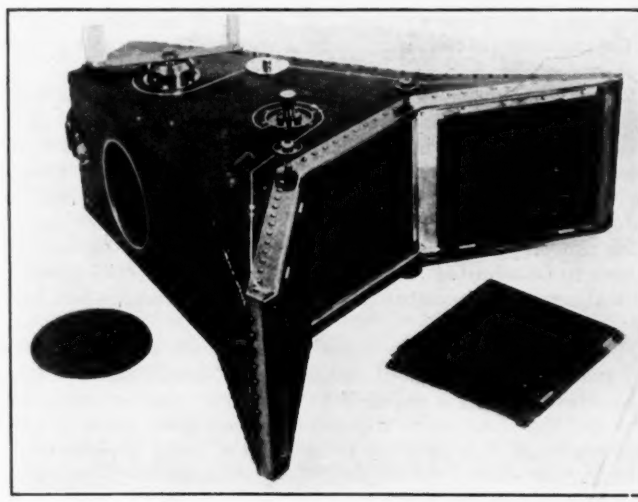

Fig. 5 Tri-Lens Camera Magazine without Camera Body

T-1 Tri-Lens Camera

The type T-1 aircraft camera is also an important and valuable unit used extensively by the U. S. Government Air Service to obtain overlapping photographs in series for making maps and military reconnaissances. The DH-4B-P-1 airplane is specially fitted to accommodate it. This camera, known as the Bagley or tri-lens camera, was designed by Major Bagley of the U. S. Air Service. It takes a film 6 in. wide by 380 ft. long and gives 190 exposures which are sufficient to photograph a terrain 9 miles wide and 190

miles long at an elevation of 15,000 ft. with the photographs overlapping 60 per cent.

Camera Base. The T-1 tri-lens camera consists of two major parts, a base and a magazine. The base, Fig. 4, has three compartments, each fitted with a lens and a focal plane of thin glass and each designated respectively by the letters A, B, and C. The compartment letter and the number of the camera are etched on each glass focal-plane plate, forming a stencil which automatically labels the negatives and, consequently, each photograph. The three lenses are mounted with between-lens automatic shutters which are released simultaneously by a three-pronged plunger. The center lens has a focal length of about $6^1/_2$ in. The side lenses have focal lengths of about $7^1/_2$ in., which, although they vary in different cameras, are carefully matched in the same camera. Each lens has a disk-shaped color screen between the two parts of its front element. The optical axis of the middle lens stands approximately vertical; the optical axes of the side lenses are inclined 35 deg. toward the center lens, this arrangement giving a total angular scope of 110 deg.

The center focal plane has two level-bubble vials which are aligned at right angles to each other. They stand practically in the focal plane, and their images are registered on all negatives of the center chamber. The base is so constructed that the side focal planes form dihedral angles of exactly 35 deg. with the central focal plane.

Magazine. The magazine has a capacity sufficient to receive single rolls of film 6 in. wide and 380 ft. long. It is equipped with two film-spool seats, a crank to wind the film, two level-bubble vials set on top in the form of a T, a dial which indicates the proper length of film to wind off for each exposure, a handle to lift the camera, and three cloth-faced pressure plates which hold the film against the focal-plane plates. The dial is connected to the film at the winding spool by means of gears, a shaft with a universal joint, and a sharp-toothed wheel, which bears against the film near its edge. One revolution of the dial releases enough film for one exposure. Rollers are placed at all points where the film turns when being drawn along its path. The path of the film is indicated on the crank face of the magazine by a heavy white line with arrows, as shown in Fig. 5.

Release Mechanism. The release mechanism consists of a lever, a counter, a plunger, and a stop watch mounted on a metal plate. It is mounted on bars in the cockpit on the right-hand side of the observer where he can easily reach the lever. A release cable forms the connection between the release mechanism and the camera.

Adjustable Mount. The adjustable mount supports the camera in its proper position in the observer's cockpit. It permits the camera to be adjusted to the level position and rotated about its vertical axis to compensate for crab. The mount rests on cushioned clamps.

View Finder. The view finder is a duplicate to those used in K-3 and K-1. This type of camera is used largely for very large areas where maps are required to small scale for reconnaissance purposes, and as an aid to alignment between given points of great distances where line maps are to be made to much larger scale for closer survey study.

The Transformer

It will be seen from the illustration of this camera that the center lens is vertical; the other two lenses are at an angle. Therefore one vertical and two oblique views are taken. The next step is to change or transform the two obliques to verticals, making one complete vertical. This is done by means of a device called the transformer. Projecting the negatives in this device through the required angle brings the photographs taken with the oblique lenses on the same plane as that of the photograph taken with the center lens. The photographs from the oblique negatives labeled A and C and the center photograph B are mounted and joined to form a single composite photographic survey. The camera covers approximately three times more area than the K-3 or K-1 in the same flying time. The camera will photograph an area about 1700 square miles in two hours' actual flying time. This, of course, is just the first step but a very important one in making the survey.

Developing Outfit

When the film is received from the flying crew, the next step is to develop it. The Eastman aero-film developing outfit, shown in Fig. 6, is suitable for the K-3 and K-1 cameras and produces the most satisfactory results. It consists of a transfer fixture mounted on a stand, a circular developing tank mounted between journals that are in turn mounted on a carriage supported by four heavy castors, two rinsing tanks, and a fixing tank. These tanks are about 21 in. in diameter.

The transfer fixture is used for winding the exposed film and protecting apron of kodaloid upon the reel. The illustration shows the apron on the upper reel on an intermediate spool, and the two partially wound upon the lower reel. When the winding operation is completed the lower reel is deposited in the developing tank set upon the standard, upon which it may be revolved during development. After developing, fixing, and washing are done, the reel is again put on the transfer fixture, where the apron is rewound while the film is placed upon a revolving drying rack.

In the construction of this outfit no expense has been spared to produce perfect results, on account of the value of the film which unexposed is worth about $45 per roll of 75 ft. in the United States. In the reels and tanks, respectively, bronze and monel metal

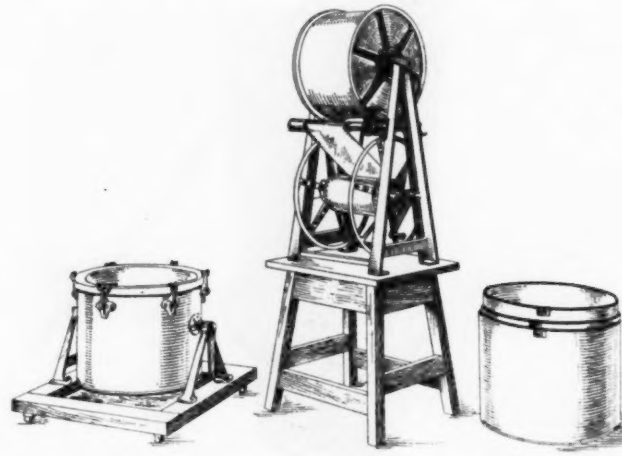

Fig. 6 Eastman Aero-Film Developing Outfit

have been utilized because they are not affected by the chemicals used in developing. Rigidity, durability, and smoothness of operation have all been attained in this apparatus the same as in the other apparatus already described. This developing outfit alone cost nearly $900.

Drying Reel

The drying reel is a circular drum about 8 ft. in diameter by 8 ft. long, built of skeleton design similar to that of a squirrel cage, driven by motor and revolving at about 500 r.p.m. The film is wound on to this drum in a spiral, fastened at each end with special clip attached to rubber bands about 12 in. long.

The process of drying the film must be carefully done to avoid uneven contraction, as the amount of shrinkage must be known and taken into consideration in calculating the ratios when adjusting the print to scale.

The film having been developed and dried, the roll is then cut at the space between each exposure; each negative is then given a number, and contact prints are made on a special printer electrically operated. In this operation no particular care is used in getting each print to a uniform tone. These are really trial prints used in the first process of making the map to prove whether or not the area required to be mapped has been fully covered.

Printing

The next process is to print another set of the negatives of photographic quality as to definition, uniformity of tone, and also to scale. The adjusting to scale is done with a special horizontal camera, mounted on a bedplate about 10 ft. long with machined ways. The lens and copy board are adjusted by means of a special graduated scale and accurately cut racks and pinions. This machine must have true alignment in every direction as the corrected prints must be correct to close limits as well as to photographic quality.

The prints now being adjusted to scale are then matched together by overlapping them in the order in which the photographs were taken from the air and are accurately cemented to the ground controls laid out on special compo board which is secured to rigid frame work.

The Stereoscope

When two aerial photographs are taken from the same altitude in such a manner that there is an area of the earth surface shown in both photographs, it is possible by the arrangement of mirrors, or lenses, or a combination of both, to blend together the almost identical photographs of the area and to obtain a very startling result. Viewed separately, the images in the photographs appear flat and it is impossible to detect changes in elevation except in a general way, but when the two photos are properly blended together by means of the stereoscope, the flat surface of the photographs no longer appears, but instead we appear to see a small-scale model of a relief map of the area on which the hills, houses, trees, and other objects seem to stand out from the photograph, and all objects appear as if modeled in some solid material at their proper scale and in proper position in relation to each other.

Fig. 7 Method of Using Stereoscope

By an inspection of the photographs in this manner, as shown in Fig. 7, it is easy to make comparisons of relative heights of different points on the ground, and by sketching lines through all points of apparent equal elevation it will be found possible to obtain fairly accurate contour lines. The vertical interval between these lines is a little more difficult to obtain, but if two or more spot heights are known either by measurement on the ground or by calculation from the prints, it will be possible to interpolate fairly accurately and to sketch in the contour lines at regular vertical distances apart.

The aerial photographs for stereoscopic use must be taken in a different manner from those which are required to be used for mosaic work. In making a mosaic where it is desired to match prints together to form a scale map of a certain area, it is most desirable to fly as high as possible and to use a lens of long focal length in order to obtain as little displacement as possible of points of different elevations, but when taking photographs for stereoscopic study, it is desirable to obtain as much displacement as can possibly be done, and for this purpose a lens of short focal length should be used and the airplanes should be flown at a comparatively low altitude. The displacement, or distortion, which is undesirable in making a mosaic, is exactly what is required to show relief in the stereoscopic photographs. The photographs must be taken in such a manner that there is a short interval of time between the two exposures, during which time the camera has moved in horizontal direction, but has retained the same altitude. The greater the interval between the photographs, the greater will be the exaggerated effect of the relief of the objects in the photographs.

Gyroscopic Stabilizer

Extensive experiments have been carried forward during the past year, looking toward that most desirable improvement for the making of aerial surveys, namely that of scaling distances accurately with a minimum amount of ground control. It is hoped that the necessary refinement will be attained during the next few months. The accomplishment of this result will depend largely on the completion of a special gyroscopic device designed to maintain the camera in a vertical position. A final model is now nearly completed and if successful will practically solve the problem that has been the bugbear in aerial surveying, namely, that of tilt. Negatives showing only very small degrees of tilt have to be adjusted in the printing process to correct for tilt. All prints have to be brought to the required scale, and to do this a different ratio of enlargement and reduction is required for every print. This necessitates a fine calibrated adjustment of the enlarging and reducing camera.

The Stereocomparator

Another important instrument but little used, if any, in this country, invented and developed by Dr. Pulfrich, is used abroad for putting in contours which are necessary, particularly for maps used in water-power development. The machine is known as the "stereocomparator." This machine puts in the contours mechanically. The principal reason these machines are not used in this country up to the present is their high cost, and the general impression among those who have inspected them is that it takes a long time for a man to operate them efficiently. Engineers in this country have been experimenting for several years in an effort to design a more simple and less costly machine for putting in contours and have met with more or less success. Domestic devices, the author is informed, will only put in 20-ft. contours, where 5- and 10-ft. contours are very often necessary.

The Autocartograph

The next apparatus worthy of mention is a device or combination of devices called the "autocartograph." This is an instrument qualified for the plotting of stereophotogrammetric views with axes set at will.

The principal parts of the autocartograph are:

1 Observing system
2 Surveying system, formed by two computing theodolites, which are coupled compulsorily by levers
3 Plotting system.

As an essential substance of the instrument it is to be observed that the reconstruction of the map from the surveying plates is based on the same principle as the terrestrial topography, i.e., sectioning the points and determining the vertical angles with a view to fix the height of the points. The only differences are that instead of contemplating the real (unmoving, invariable) ground, one contemplates an optic (unmoving, invariable) model of it, that the sectioning of the points is not done point for point but successively, and that the height is not ascertained by calculation but mechanically.

Owing to this adaptation to the usual proceeding of practical geodesy, well proved since many a decade, the mechanism is of somewhat simple construction. Accordingly the autocartograph produces so few errors that the highest possible precision of its work is warranted.

This ingenious apparatus was designed by Dr. Hugershoff and built in the works of Gustav Heyde at Dresden. It represents the highest degree of mechanical and technical precision. Very few, if any, of these apparatus are being used in the United States.

The Stereoplanigraph

Still a later development which appears practical as applied to aerial surveying is the "stereoplanigraph," invented by Dr. Bauersfeld of the Zeiss works. The principal advantage of the apparatus is that it is entirely immaterial how the pictures are taken. Pictures can be taken horizontally, vertically, or obliquely under any angle to a vertical or horizontal plane. Also the position of the two cam-

eras to each other and their orientation to the vertical line is not fixed. It is only necessary that the photographs show the same landscape. As a special advantage stress is put upon the fact that the connection between the drawing pencil with the different movements of the measuring system is not rigid but can be regulated at will. It is further possible to connect with the planigraph a second drawing board so that the plans can be worked out simultaneously on different scales. Thus the relation of scale of the measuring system and of that of the drawing one is not rigid but changeable.

The solution of the three-point problem in space is here a simple matter. In case that on a pair of plates the location of three or more points is known, the alignment of the cameras is at first made approximately. Either we get for each point an equation with three unknown quantities, or we may try to solve these equations by a graphical method directly with the apparatus. In the first case we get the coefficient for each equation from the machine directly and can then solve them, in the second one a graphical solution of the problem is attained. One will be able to adjust, inside of two hours, the plates in the stereoplanigraph to start to work them out, while at present the calculation of a base line (two stations) of the three-point problem in space takes about sixteen hours.

These three instruments have been mentioned as they have been used considerably in European countries and are the most popularly known to the author. Several demonstrations have been made in this country with these machines, but none has been sold to the Government or others for use in connection with aerial mapping.

Discussion of Steam-Research Reports[1]

By J. H. KEENAN,[2] SCHENECTADY, N. Y.

THERE is little doubt that those turbine manufacturers who are building turbines to work at steam pressures from 500 to 1200 lb. per sq. in. are vitally interested in steam research. The designer who lays out a turbine for such steam conditions is confused and perplexed by the very serious differences existing between the various steam tables from which he may obtain his data. For example, if he were to compare values of the adiabatic heat drop from 500 lb. per sq. in., 725 deg. fahr., to 150 lb. per sq. in., as given by Goodenough, Marks and Davis, Stodola, Callendar, and Knoblauch (see Table 1), he would find them varying from the Marks and Davis value of 126.4 B.t.u., to the Callendar value of 132.3 B.t.u., a variation of 4.6 per cent. He would find the initial specific volumes varying from Knoblauch's 1.318 cu. ft., per lb. to Marks and Davis's 1.402 cu. ft., per lb., a variation of almost 6 per cent. Between 1000 lb. per sq. in., 750 deg. fahr., and 200 lb. per sq. in., he would, strangely, find a smaller variation in heat drops, 2.5 per cent, but a still larger variation in initial specific volumes, 8 per cent. The compilers of the steam tables cannot of course be held accountable for these variations, in that most of the values compared are extrapolations of extrapolations. But it is natural that a manufacturer of high-pressure turbines would lose no time in making use of the most recent data available on high-pressure steam.

TABLE 1 COMPARISON OF STEAM TABLES AT HIGH PRESSURES

		Goodenough	Marks & Davis	Stodola	Callendar	Knoblauch
Upper limit of table (lb. per sq. in.)		800	600	1422	500	850
Means of extrapolation		Formula	Graphic	...	Formula	Graphic
1000 lb. per sq. in., 750 deg. fahr.	H to 200 lb. per sq. in.	162.8	163.8	163.8	166.7	164.7
	Specific volume	0.659	...	0.654	0.676	0.625
500 lb. per sq. in., 725 deg. fahr.	H to 150 lb. per sq. in.	131.8	126.4	131.7	132.3	130.5
	Specific volume	1.356	1.402	1.346	1.362	1.318

One year ago at the meeting of the A.S.M.E., Dr. Davis presented his latest Joule-Thomson-effect data. They included tests ranging from 40 to 560 lb. per sq. in. Dr. Davis very kindly put these data at the disposal of the General Electric Co., and offered to develop the formulas necessary to the calculation of a steam chart.

He reformulated his Joule-Thomson coefficients, using a family of curves which was more convenient in itself than the original formulation. This step made necessary a complete revision of the calculations from which Dr. Davis obtained the charts which he presented at the last December meeting. As the first step in this revision we calculated the pressure-temperature relation along constant-total-heat lines throughout the superheated region, using a finite-step method of integrating the Joule-Thomson coefficients (the slope values of the constant total-heat curves).

From the intervals between these curves the values of the ratio of C_p at any pressure and temperature to C_p at zero pressure and the same total heat were found and a chart of those values was drafted. Knoblauch's various sets of determinations of C_p were divided by the proper values of C_p ratio to determine points for a curve of C_p at zero pressure. From this curve and the C_p ratio chart the values of C_p over the entire field could be determined. Values of the product of μ (the Joule-Thomson effect) and C_p were then calculated. This step marked the completion of the revision of the original calculation.

An expression for μC_p in terms of pressure and temperature was developed by Dr. Davis, who has discussed that part of the work in more detail. Briefly, the type of formulation adopted required a variable correction term, and the resulting formulas for volume, entropy, and total heat included integrals of the correction term and a coefficient which could be determined from the difference between the volume formula and the best available volume determinations. The use of this coefficient was suggested, and to a large extent justified, by a study of the limit approached by pv/RT for air as T increases indefinitely.

But in the calculation of the steam chart we have felt it to be desirable to avoid complexities as much as possible. The constant-total-heat line chart offered an opportunity to dodge the total-heat formula. Thus, to get one of the ordinates of our Mollier diagram only this chart, supplemented by a curve of total heat at zero pressure is needed. The zero pressure values are simply

$$H = H_0 \int_{T_0}^{T} C_p dT$$

where H_0 is a constant to which we have assigned a value which will bring our total heats into agreement with those of the Marks and Davis steam tables at 320 deg. fahr. saturation.

No such short cut has been found for the volume and entropy calculations. However, the volume calculations are in close agreement (<0.1 per cent deviation) with the Knoblauch volumes which cover pressures from 25 to 160 lb. per sq. in. and temperatures from 300 to 374 deg. fahr.

The entropy formula may be found from the expression for total heat at zero pressure and from the volume formula. In other words, the entropy formula may be considered as an expression for the entropy at the desired temperature and zero pressure, plus the entropy increase during a constant temperature change from zero pressure to the pressure desired. The first step is dependent only on our C_{p0} line, the second can be obtained by an integration of the equation:

$$\left(\frac{\partial N}{\partial p}\right)_T = -\left(\frac{\partial v}{\partial T}\right)_p$$

hence it is dependent only on the volume formulation.

For the steam-engine designer a steam chart may serve two purposes: it may be a basis for comparison of the performances of steam engines, or it may be a record of the properties of steam. To serve as a basis of comparison has been its more usual function in the past. The specific volume given might not be the correct specific volume and the total heat might be seriously in error, but the chart would still be adequate as a basis of comparison. To those who so consider it the efficiency of, for example, a turbine means nothing except as it may be compared with similar ratios obtained for other machines. Should a competitor claim an efficiency of 101 per cent they would have no logical theoretical grounds for taking exception to the claim—they would have grounds for getting busy and producing a turbine with 102 per cent efficiency. But most designers are now acquiring an intelligent conception of what happens inside of a steam engine. Consequently an adequate knowledge of the properties of steam is essential to the design of a machine which will operate within ranges of condition of the fluid which have not been thoroughly explored by engine tests.

[1] The steam research reports were published in the February, 1925, issue of Mechanical Engineering, pp. 103–108.

[2] General Electric Co.

Air Preheaters

Their Historical Development and Present Status—Data on Erected and Proposed Installations

By C. W. E. Clarke,[1] New York, N. Y.

The first applications of the principle of preheating air for combustion were in the iron-smelting industry. In 1829 Neilson "discovered" the process of preheating the air for metallurgical furnaces by the exit gases, and a number of furnaces were built using this principle. There was a gradual increase in the use of preheated air in the iron and steel industry, and by the middle of the 19th century the practice was almost universal. Apparently little was done toward the application of this principle to boiler furnaces, except for the purpose of smoke consuming.

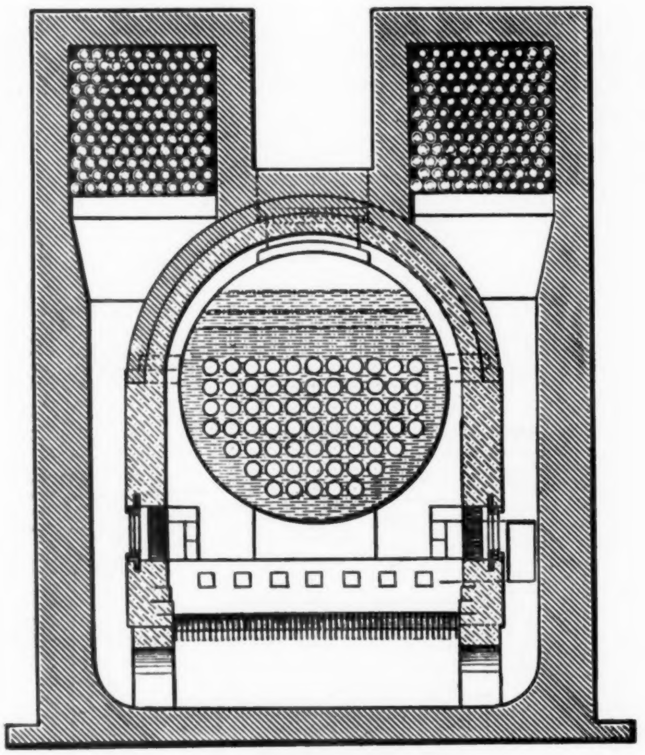

Fig. 1 Early Air-Preheater Installation Made in 1882 at Lawrence, Mass.

As early as 1839 there were some fifty patents on file in England covering methods of smoke consumption, all of them involving the introduction of preheated air over the fire or in the combustion chamber. Failure at this time to realize the benefits of recovering heat from the flue gases may be explained in part by the general attitude on the subject which is indicated in C. W. Williams' book on the combustion of coal and the prevention of smoke (1854), in which he writes:

> Were it possible to heat air without causing any enlargement of its bulk we should then be in a position to decide on the relative merits of air at any given temperature. As, however, that is impossible, it is indisputable that we gain nothing by heating the air, more especially when we do so by the suicidal means of taking heat from the very furnace in which it is to be used, while we should seriously embarrass ourselves by having to increase the draft, and which could be done only by some mechanical blowing apparatus.

Smoke-consuming furnaces of the early days contained air inlets in the bridge wall for the admission of air to the rear of the furnace which had been heated during its passage through the bridge wall. This explains Williams' reference to "taking heat from the very furnace in which it is to be used." Williams' statement seems to be fairly representative of the current ideas on the subject. Mr. D. Kinnear Clark in his book, Fuel, Its Combustion and Economy (1879), quotes Professor Brande as follows: "Sir H. Davy found . . that both the light and heat of the flames of sulphur and hydrogen were increased in air condensed four times." Then Clark says, "This is decisive against heating the air, and in favor of condensing it."

Up to 1871 no reference to air preheating for the sake of economy could be found. In 1871 to 1874 there were several experiments and tests on boiler furnaces using preheated air. In 1874 *The Engineer* states that a Ponsard furnace similar in construction to the Siemen's furnace, was successfully applied under an "Elephant" boiler. This test showed an evaporation of 9.12 with the Ponsard furnace as against 5.45 with the Elephant boiler without the Ponsard attachment. *The Engineer* further states: "We have often pointed out the advantage to be derived from the use of heated air in steam boilers. One great point appears to be its power of using up inferior fuels to advantage." It is strange that this important characteristic of preheated air should have been pointed out at that time and yet apparently have been altogether lost track of since.

The first recorded instance of an air-preheating system for the avowed purpose of thermal gain was in 1882 when an installation of air preheaters was made at Lawrence, Mass., under patents of Obadiah Marland dated 1878. This installation was tested by J. C. Hoadley, of Boston, and the results published in his book Warm-Blast Steam Boiler Furnace.

The heater used in this case is shown in Figs. 1 and 2 and was of the horizontal tubular type, contained 10 baffles in the air passage, but had only a single pass in the flue-gas passage. The tests show the following temperature conditions:

Location	—Temperatures, deg. fahr.— Without preheater	With preheater
In heart of fire	2493	2793
At bridge wall	1340	1600
At pier	895	1050
In smokebox	373	375
Air admitted to furnace	32	332
Gases to stack	373	162

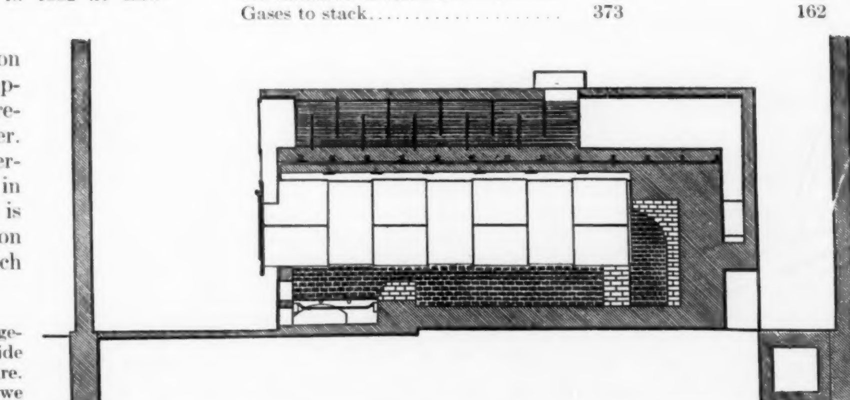

Fig. 2 Longitudinal Section of Lawrence Air Preheater

Considering the difficulty experienced even now in making measurement of high temperatures, one is inclined to doubt the accuracy of the figures given for the "heart of the fire." However, the temperature measurements were made with great care, using a platinum-ball calorimeter, and though errors are probably present they should be of small magnitude and fairly constant.

It will be noted that the air is heated through 300 deg. while the gases are cooled through but 211 deg. This is explained as being partially due to heat absorption from the boiler and setting. Mr.

[1] Dwight P. Robinson & Co. Mem. A.S.M.E.

Presented at the Second Annual Power Meeting, Chicago, Ill., Jan. 14 and 15, 1925, of the Chicago Section of The American Society of Mechanical Engineers.

Hoadley says, "This difference or something like it was constantly observed." The average of the ash in per cent of the total fuel fired was for the tests with the preheater 12.12 and without the preheater 13.41.

The almost universal opinion of English writers of the last century was that preheating air was a fallacy and could not be anything but detrimental to combustion efficiency. It is probably for this reason that this method of increasing the efficiency of steam generation did not keep pace with other developments in steam engineering.

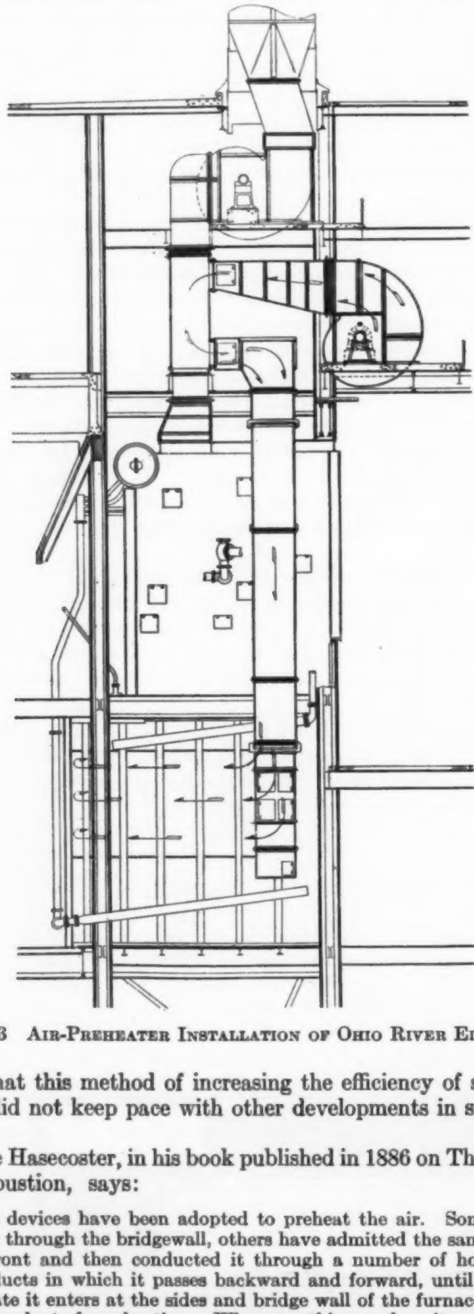

FIG. 3 AIR-PREHEATER INSTALLATION OF OHIO RIVER EDISON CO.

George Hasecoster, in his book published in 1886 on The Triumph of Combustion, says:

> Various devices have been adopted to preheat the air. Some have admitted air through the bridgewall, others have admitted the same by small flues in front and then conducted it through a number of horizontal expanding ducts in which it passes backward and forward, until finally in a heated state it enters at the sides and bridge wall of the furnace and unites with the product of combustion. Whenever this was done it was invariably at the cost of economy, because the brick walls absorb heat from the gases and flues conduct it to the cold air passing through the air ducts. Most of these devices, however, have progressed very little in the accomplishment of the aim for which they were intended, and the immense waste is still going on.

So even at this late date there seems to have been little appreciation of the real value of preheated air.

In 1902 the author designed an air-preheating device for the East St. Louis Plant of Armour & Company, consisting of a space along and about the flue through which air for the furnace passed. The device was not successful, however, due to insufficient surface and difficulty of cleaning. A description and cut of the device will be found in the Transactions of the A.S.M.E., vol. 45, 1923, p. 567.

In 1921 W. H. Patchell presented a paper before the Institution of Mechanical Engineers giving such data as he was able to collect at that time on tests of preheater installations. He reported eleven tests, the first made in 1898. The gain in efficiency due to heat reclaimed by the preheater was given for eight of the tests. The maximum of these figures was 5.4 per cent, the minimum 3.1 per cent, and the average 4.35 per cent.

Within the last few years the use of preheaters has been greatly stimulated. A great many of the large installations being made today include air preheaters of some sort. The value of this method of increasing power-plant efficiency has been fully demonstrated and air preheaters have become a permanent adjunct in the steam power station.

At the present time there are a number of flue-gas preheaters on the market, divided into three types: namely (1) Flat plate; (2) Tubular; and (3) Rotative. Detailed descriptions of these types may be found in *Power*, vol. 60, no. 23, Dec. 2, 1924, p. 884.

The plate-type preheaters are all of similar design, consisting of alternate spaces for gas and air separated by thin plates. They should be and are, where conditions permit, operated on the counterflow principle. The difference between the various makes is only in detail of construction. It is of course of the utmost importance that the elements be gastight, and any design that fails in this respect is inferior.

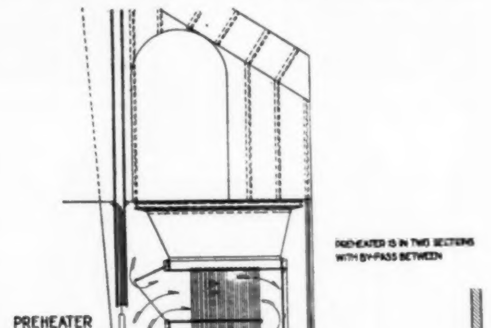

FIG. 4 TUBULAR AIR-PREHEATER INSTALLATION, LOS ANGELES GAS & ELECTRIC CORPORATION

The tubular types consist of tubes for the passage of the flue gases with arrangements for passing the air over their external surfaces. There are ordinarily several passes for the air, so arranged as to give a counterflow between the gas and air.

The rotative type consists of a rotating mass of metal so built up as to provide a multiplicity of passages through it for the gas and air. Half of the mass is in the flue and half in the air passage. As the mass revolves the metal absorbs heat from the flue gases,

carrying it around into the air passage where the absorbed heat is given up to the air.

Experience to date with the plate-type preheater has shown little trouble from fouling. A number of installations have been provided with soot blowers, though there are fully as many with no provision for cleaning except by hand through the access doors. It is very probable that with some grades of fuel soot blowers will be necessary. This type of heater should always be installed with the gas and air passes vertical to facilitate self-cleaning. There is some vibration of the plates, which tends to dislodge any adhering material. Cinders entrained in the gases should have a very considerable scouring action and therefore aid in keeping the surfaces clean. With certain fuels containing large amounts of moisture and sulphur there will doubtless be considerable corrosion, but on account of the structure and low pressure differences in this apparatus the metal might be reduced to paper thickness before replacement should be necessary. Figs. 3 to 6 show typical installations of air preheaters.

PREHEATING BY STEAM

Preheating air with steam extracted from the turbine has been

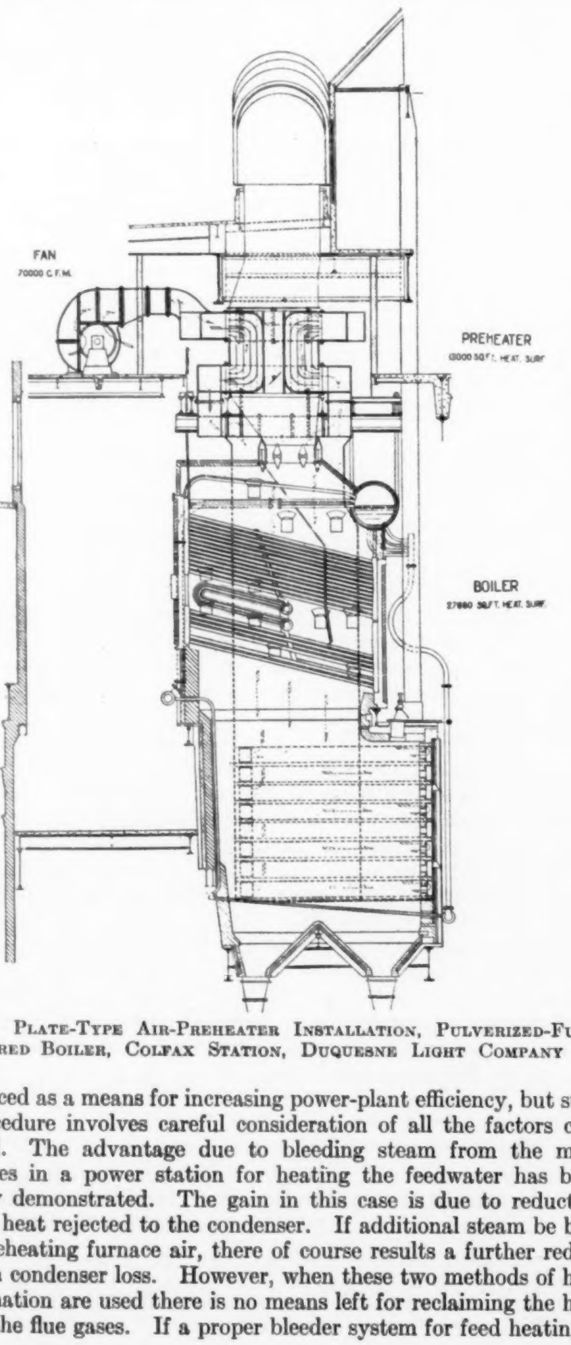

FIG. 5 PLATE-TYPE AIR-PREHEATER INSTALLATION, PULVERIZED-FUEL-FIRED BOILER, COLFAX STATION, DUQUESNE LIGHT COMPANY

advanced as a means for increasing power-plant efficiency, but such a procedure involves careful consideration of all the factors concerned. The advantage due to bleeding steam from the main turbines in a power station for heating the feedwater has been clearly demonstrated. The gain in this case is due to reduction in the heat rejected to the condenser. If additional steam be bled for preheating furnace air, there of course results a further reduction in condenser loss. However, when these two methods of heat reclamation are used there is no means left for reclaiming the heat from the flue gases. If a proper bleeder system for feed heating is installed which heats the water to the highest temperature permitted by the steam conditions prevailing in a given installation, there is not sufficient heat capacity left in the feedwater to warrant the installation of economizers. Under such conditions the only possible method of reclaiming the heat of the flue gas is by an air preheater. Then if full advantage is taken of this means of heat reclamation there is no heat capacity left for which a steam pre-

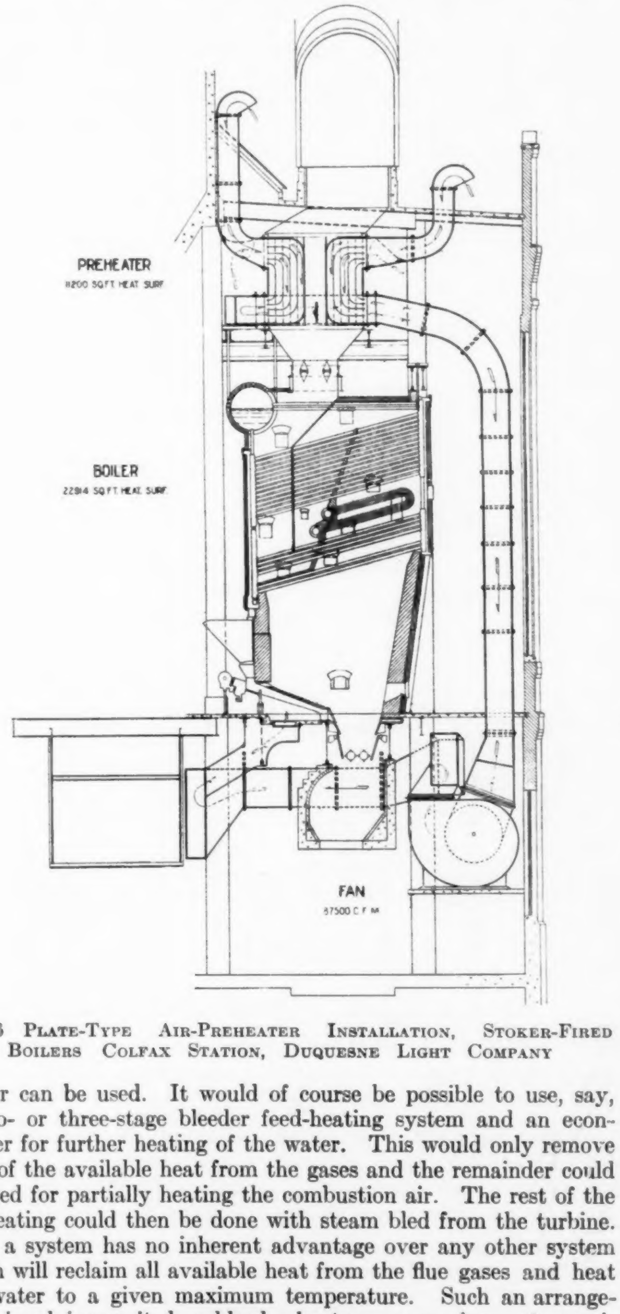

FIG. 6 PLATE-TYPE AIR-PREHEATER INSTALLATION, STOKER-FIRED BOILERS COLFAX STATION, DUQUESNE LIGHT COMPANY

heater can be used. It would of course be possible to use, say, a two- or three-stage bleeder feed-heating system and an economizer for further heating of the water. This would only remove part of the available heat from the gases and the remainder could be used for partially heating the combustion air. The rest of the air heating could then be done with steam bled from the turbine. Such a system has no inherent advantage over any other system which will reclaim all available heat from the flue gases and heat the water to a given maximum temperature. Such an arrangement involving as it does bleeder heaters, economizers, steam air heaters, and flue-gas air heaters, contains every possible complication and produces no more than the simpler arrangement containing a bleeder system for heating the feedwater and a flue-gas air preheater for reclaiming the heat from the furnace gases.

In order to show the relative merits of steam air preheating and preheating with flue gases, the heat rates for two cycles have been calculated. The characteristics of the two are shown on the diagrams, Figs. 7 and 8.

The basic data for these calculations are those received for and used in connection with the turbine now being installed in the Seal Beach Station of the Los Angeles Gas and Electric Corporation. Though more advantageous locations for the bleeder openings in connection with the steam-air-preheater cycle would result in a slightly better efficiency the difference would be small. Also

if the air heating were done in two or perhaps three steps there would be a somewhat lower heat rate. The limited time available for the preparation of this paper did not permit calculation of these additional cycles.

It is assumed that in both cases the air for combustion is heated from 70 to 300 deg., except that in one the heating is done by steam and in the other by the flue gases. It is also assumed that in both cases the flue-gas temperature is reduced from 525 to 300 deg. in one by the air preheater and in the other by the economizer.

The heat rates have been calculated without including combustion efficiencies or other boiler-room losses. It may safely be assumed that the efficiencies of the boiler equipment would be the same for the two cases since the combustion-air temperatures and final gas temperatures are the same for both. In computing the

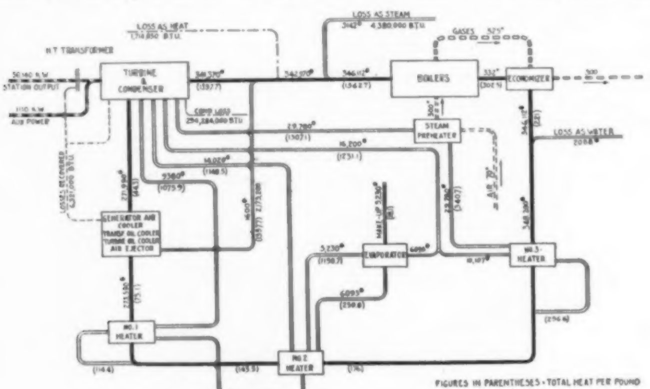

Fig. 7 Flow Diagram with Steam Air Preheater, Economizer, and Three-Stage Bleeder System

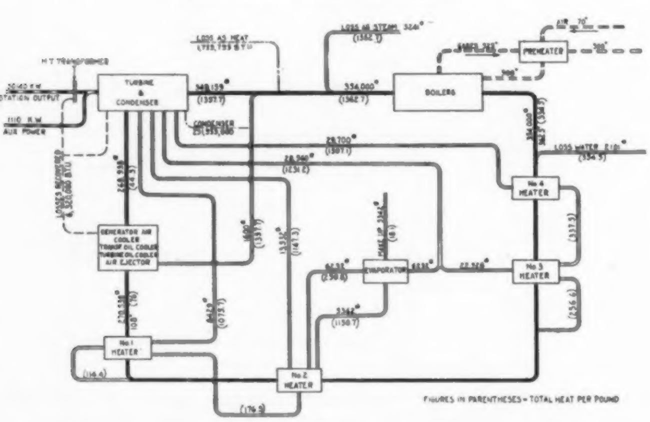

Fig. 8 Flow Diagram with Flue-Gas Air-Preheater and Four-Stage Bleeder System

heat rate for the case involving steam air preheating the total heat added to the air is deducted from the total work charged to the boiler room. Under these conditions the heat rates based on net station output and exclusive of boiler-room losses are:

With steam air heating and economizer.....	12,165 B.t.u. per kw-hr.
With four-stage bleeder and flue-gas preheater	12,085 B.t.u. per kw-hr.

Furnace Conditions

Experience has shown that the introduction of heated air to the furnace results in a considerable improvement in combustion. The air for combustion must be heated to the temperature at which combination of the carbon and oxygen will occur before combustion can be complete, and this of course consumes time. If the air could be introduced into the fuel bed at this combining temperature, the only time requirement would be that necessary for disintegration or volatilization of the fuel, and this is, of course, a function of the exposed surface area per unit of volume of the fuel itself. The heated air would have the effect of bringing the combining zone closer to the fuel bed and probably reducing the furnace volume necessary for the combustion of a given weight of fuel per unit of time. It should also have the effect of causing more complete combustion in the fuel bed itself on account of lessening the necessity for downward travel of heat through the fuel bed. This latter supposition is borne out by the very considerable reduction of combustible found in the ash from furnaces using preheated air as compared with those using cold air.

The same general considerations hold good with reference to pulverized-fuel furnaces. It is the time factor required for heating the fuel and air that is largely responsible for the long flame travel and consequent large furnace volumes required with the burning methods now on the market. It has been observed in the furnaces recently installed in the Colfax Station that when preheated air is used the flame is shortened.

It appears that any tendency toward slagging is accentuated with preheated air. The general temperature level in the furnace is of course raised and the solidification of the slag consequently retarded. This results in a freer running of slag on the furnace walls and consequently rapid erosion of the brickwork. It is the author's opinion that unless an entirely new type of refractory is developed, pulverized-fuel furnaces using preheated air cannot be operated successfully at high ratings except with special cooling arrangements for the furnace walls.

Though the draft loss through air preheaters is relatively small, it is sufficient to place a definite limit upon the ratings that can be attained with a given equipment on natural draft. It is of benefit so to install preheaters as to provide an open passage through them closed by a damper which may be opened when extraordinarily high ratings are desired and efficiency may for the time being be sacrificed.

There is little definite information available regarding the characteristics of preheated air in improving combustion with low-grade fuels. As noted above, this was pointed out in 1874 by *The Engineer*.

Data have been collected on preheater installations and are given in tables on pages 180 and 181. Table 1 includes only installations in operation at the time this paper was written and Table 2 covers installations in course of erection or on order.

The figures given in these tables are exactly as they were received and there are some that seem doubtful. Time was not available in which to check the data, part of which, as will be seen, came from abroad.

The author acknowledges the assistance given him by those who furnished the data for these tables.

Discussion

R. J. S. PIGOTT[1] contributed a written discussion in which he said that the paper was particularly timely, in that, in spite of the recent considerable increase in the use of preheaters, there were very few collected data available. With regard to the desirability of the air preheater as a power-station auxiliary, the salient features were as follows:

The cyclic efficiency of the turbine room as a whole was improved by stage heating. The higher the point to which bleeding was carried, the greater the cyclic efficiency. There had been some tendency to take the view that bleed heating could not be economically carried above 300 deg. fahr., but this limitation was set by considering the turbine alone, and not by considering the whole group, including an economizer. If bleed heating was carried higher than 300 deg. with the intent to eliminate the economizer, it would certainly still pay, especially if the upper limit bleeding was done from house turbines instead of from the main unit. As the author had stated, when the bleeding was carried up to the point that the economizer had no longer an opportunity to add heat to the feedwater, the only remaining method of recovering sensible heat in the flue gases was by way of the air preheater. It was perfectly possible to abstract as much heat from the flue gases by means of the air preheater as with the economizer. By using the air preheater in this manner, the maximum opportunity for raising the turbine-room cyclic efficiency was offered, and in the boiler room the same heat from the flue gases could be recovered, but with additional indeterminate improvement in combustion efficiency.

[1] M. E., Stevens & Wood, Inc., 120 Broadway, New York, N. Y. Mem. A.S.M.E.

There was no question that the volume of powdered-coal furnaces as now installed must be ultimately greatly reduced and, as Mr. Clarke indicated, preheated air was one of the means by which the necessary volume of furnace could be cut down. As a piece of apparatus the air preheater had some advantages over the economizer. The principal advantage appeared to be that it was not under high pressure. The second advantage was that for the same heat recovery it was somewhat less expensive to install.

With regard to cleaning, which had been noted in the paper, there was certainly very much less trouble to be apprehended from the preheater than had been the case with the economizer. Of course, it was true that even with the economizer installed on powdered coal there need be little trouble from fouling if there was considerable bleed heating prior to the economizer. This was largely due to present-day conditions, in which the cinders from powdered-coal fires were very finely divided, economizer tubes were steel instead of rough cast iron, and the water entering the economizers was always hot enough to avoid sweating. It would appear that in most air-preheater installations little or no special provision for cleaning need be provided.

Mr. Pigott was in hearty accord with Mr. Clarke on the question of flue-gas preheating versus steam preheating. It is possible to produce nearly the same efficiency either way, but physically, the substitution of steam preheating for the flue-gas preheating inevitably subdivided and complicated the apparatus.

The simplest layouts unquestionably obtained where all the feedwater heating was done by bleed heaters, no economizer being employed, and where all of the flue-gas heat was abstracted in an air preheater and passed direct to the fire. The possibility of relatively simple duct layouts with the preheater was very evident from the cut showing the Ohio River Edison Company installation now going in at Toronto on the Ohio River. In this particular case the forced-draft fan was located near the top of the building, and was used to recover practically all stray heat losses in the plant, and to provide a definite mechanical ventilation for the station.

In order to avoid the risk of slagging with preheated air this particular installation was provided with a little more than usual furnace-wall protection. The furnace was equipped with water screens on three sides and on the bottom of the furnace very much like Mr. Clarke's installation at the Allegheny Steam Heating Company, but in addition, the hollow wall carrying the air supply to the burners had also been used. For walls of these heights the hollow wall had some advantages in weight reduction and protection; moreover, it was just about as easy to distribute air through the walls as it was to provide multiple ducts external thereto. This boiler had a little more water-screen surface than most installations so far, having 10 per cent of the total surface in the furnace. In view of the rather chaotic state of information at the time of the design of this boiler, it had been believed that the additional water-screen surface would about offset the effect of air preheating. Up to the present time it did not appear that the use of preheated air in such a water-screened furnace was likely to occasion any marked trouble.

For the present it seemed fairly safe to say that the use of preheated air would improve combustion conditions as far as efficiency of the boiler was concerned, and would somewhat raise the maximum capacity, and that the water-cooled furnaces should provide sufficient protection against the increased tendency to slag.

Henry Kreisinger[1] wrote that he agreed with the author that air heaters should be more generally used than they were at present. He felt that as more air heaters were in use it would be found that their upkeep would be smaller than that of upkeep of economizers.

The only statement Mr. Kreisinger did not quite agree with was toward the end of the paper, under Furnace Conditions: namely,

> The same general considerations hold good with reference to pulverized-fuel furnaces. *It is the time factor required for heating the fuel and air that is largely responsible for the long flame travel and consequent large furnace volumes required with the burning methods now on the market.* It has been observed in the furnaces recently installed in the Colfax Station that when preheated air is used the flame is shortened.

It seemed that the statement made in this paragraph was overdrawn, particularly the part which he had italicized. With hollow-wall construction the air was preheated by passing through the hollow walls, and enters the furnace at a temperature of about 300 deg. fahr. This was true especially of the air entering the furnace through the highest two or three compartments, which air came in contact with the incoming coal first, and the preheating should speed up the ignition and shorten the flame. His organization had not been able to find an appreciable difference in the length of flame and the furnace volume required between the hollow-wall and solid-wall furnace construction. It might be true that with air preheaters the temperature of the air entering the furnace was higher than with the hollow-wall constructions, and that the flame might be somewhat shorter. However, they were not justified from what they knew today, in saying that "It is the time factor required for heating the fuel and air that is *largely* responsible for the long flame travel and consequent large furnace volumes required." He did not think that a *radical* change in the length of flame and furnace volume required for nearly complete combustion could be expected by the use of air heaters.

W. E. Caldwell,[1] who opened the oral discussion, asked whether the total auxiliary power would not be slightly greater with preheaters than it would with economizers; that was to say, an economizer required only an induced-draft fan and the loss in the heat of the water was practically negligible, whereas in an air-preheater installation, in addition to the induced-draft fan, a forced-draft fan was also required. Of course, it was also evident that the proper place for the forced-draft fan was on the cold-air side of the air preheater, inasmuch as the work to be done by the forced-draft fan was directly proportional to the absolute temperature of the gases being handled.

Mr. Caldwell also asked if leakage was a serious matter with the preheated-air ducts and necessary connections. Also, of the figures that had been given, how much was contributed to the increased efficiency by the air preheater over the stage bleeding and other novel arrangements in the turbine room.

C. M. Hardin[2] said that if the author's figures were correct, four-stage heating with air preheating was more efficient than economizers and steam air preheating. There was no question but what the capital cost would be less with the four-stage heating and the air preheating, for the basic reason that with this arrangement there was only one low heat transfer. With the air preheater the unit heat transfer was around 10, 15 to 20, while with stage heating the unit heat transfer was all the way from 400 up to probably 600. With the other arrangement, with the economizers and steam preheating, there were two low heat transfers, two gases in one case and one gas in the other case, and as the gas was the limiting feature, the capital cost would be materially higher with economizers and steam preheating.

Alex D. Bailey[3] said that Mr. Abbott's reference to Fisk Street had reminded him that the subject might be put in plainer words if the two great losses encountered in any fuel-burning steam-driven station were cited, namely, the stack loss and the condenser loss. With the old equipment, the net product of his company was in the neighborhood of 12 per cent, that was, the energy delivered electrically was about 12 per cent of the heat input. It was only by the use of more efficient turbines, boilers, and boiler equipment that this had been increased, and the installation of economizers, the practice of bleeding the main turbine, and the installation of preheaters, finally, had been the great steps that had marked the improvement.

The losses in both ends of the cycle were so great that there was a very great opportunity for improvement, and it seemed to be pretty well established as to the best means of reclaiming the heat in each case.

There was no doubt about the benefits to be derived from preheated air, so far as furnace operation was concerned. In the installations of his company the heating amounted to only about 80 deg. The preheaters were behind the economizers and the gas temperatures entering the preheaters were comparatively low, yet even with that small increase they could see improvement in

[1] Research Engr., Combustion Engineering Corp., Broad St., New York, N. Y. Mem. A.S.M.E.

[1] Asst. to Genl. Supt. Power Plants, The United Elec. Light & Power Co., 130 E. 15th St., New York, N. Y. Assoc-Mem. A.S.M.E.

[2] Genl. Sales Mgr., Ross Heater & Mfg. Co., Inc., 1407 West Ave., Buffalo, N. Y. Assoc-Mem. A.S.M.E.

[3] Supt., Generating Stations, Commonwealth Edison Co., 22nd & Fisk Sts., Chicago, Ill. Mem. A.S.M.E.

TABLE 1 PREHEATER INSTAL-

Name of Operating Company	Boilers Make	Boilers Size	Boilers % Rating	Preheaters No.	Preheaters Date	Preheaters Make	Preheaters Elem'ts	Preheaters Surface	Pounds per Hour Gases	Pounds per Hour Air	Temperatures Entering Gas	Temperatures Entering Air	Temperatures Leaving Gas	Temperatures Leaving Air	Cleaning Method	Cleaning Frequency
Commonwealth Edison Company:																
Calumet Station......	B. & W.	15,089	235	1	....	C. E.	88	9,000	178,000	Not given	326	61	263	151	Water sprays on gas side	Not stated
Calumet Station......	B. & W.	15,089	...	1	....	B. & W.Tub.	...	8,773	199,000	183,000	315	70	262	130	...	.....
Duquesne Light Company:																
Colfax Station........	B. & W.	22,910	200	2	1923	C. E.	160	11,200	280,000	224,500	510	70	350	218	None	.....
Colfax Station........	B. & W.	22,910	...	1	1924	C. E.	160	13,000	200,000	224,500	510	70	350	218	None	.....
Colfax Station........	B. & W.	27,680	...	2	1924	C. E.	160	13,000	260,000	224,500	550	70	407	236	None	.....
Colfax Station........	B. & W.	27,680	221	2	1924	C. E.	160	13,000			491	86	379	252	None	.....
Eagle Paper Company, Joliet, Illinois.........	Page	2,300	***	1	***	C. E.	26	1,508	40,500	37,800	575	70	411	246	***	***
Benoist & Company, Riorges, France.......	Semi-Tub.	1,960	81	1	1922	Thermix	***	1,510	***	***	500	62	***	163	***	***
The Hague Cent. Elec. Wks. The Hague, Holland...	B. & W.	6,724	***	2	March 1920	Thermix	***	7,532	103,000	96,500	392	79	317	167	***	***
The Hague, Holland...	Mar.	7,075	***	***	***	Pratt	***	7,530	122,700	114,300	433	81	342	177	***	***
The Manchester Corp.... Barton Station........	B. & W. Mar.	16,020	***	9	Fall 1923	B. & W. Tubular	...	12,080	193,678	169,785	401	57	295	184	Hand scraper	***
Newcastle-on-Tyne Elec. Supply Company..... No. Tees Station......	B. & W. Mar.	6,980	***	10	1917	B. & W. Tubular	***	9,245	62,821	59,110	542	63	306	346	Hand scraper	***
North Metropolitan Elec. Supply Company Willesden............	B. & W.	4,780	***	1	Oct. 1923	Howden Ljungström	...	11,900	46,000	43,500	595	64	269	474	Soot blowers	3 to 4 times daily
Union d'Électricité Gennevilliers.........	Lille Stirl.	22,600	244 Approx.	5	Inst. 1921 Op. 1922	Humboldt & Thermix.	...	19,250	254,000	231,000	437	104	311	221	Scrapers	Once a week
Gennevilliers.........	B. & W. c. d.	14,850	***	10	Op. 1922	Humboldt & Thermix.	...	12,050	159,500	137,500	382	104	275	203	Scrapers	Once a week
Lutterbach Brewery.....	Semi-Tub.	2,300	***	***	***	Thermix.	***	2,800	***	***	541	117	379	242	***	***
Star Paper Mill Blackburn............	Lanc.	1,000	160	1	Sept. 1924	Howden Ljungström	...	8,000	24,000	22,600	935	83	367	659	Soot Blowers	6 times daily
Connery & Company, Inc., Chester, Pennsylvania.	Stirl.	14,217	***	1	Oct. 1924	Connery Plate	...	22,072	240,000	224,500	624	80	403	325	Air lance	Not Determined
Delaware County Electric Company																
Chester, Pennsylvania.	Stirl.	14,217	***	4	1924	B. & W. Tub.	...	22,000	***	***	***	***	***	***	***	***
Chester, Pennsylvania.	Stirl.	14,217	***	1	1924	B.&W.Plate	***	22,000	***	***	***	***	***	***	***	***
Davenport Dockyard, England.............	Wood.	4,100	218	2	1911	USCO	***	2,378	***	***	591	77	402	230	Steam lance	***
Portsmouth Dockyard, England.............	Stirl.	3,660	174	5	1913	USCO.	***	1,800	***	***	526	68	374	197	Steam lance	***
Francis Stevenson & Co., Dundee, Scotland.....	Lanc.	***	***	2 Tand.	1918	USCO.	***	4,524	***	***	794	74	450	335	Brushing	***
Central Electric Supply Company, London, England.....	B. & W. Mar.	8,619	260	4	1924	USCO.	***	9,020	***	***	382.5	99.6	279.4	211.7	Steam lance	***

TABLE 2 PREHEATERS IN PROCESS

Name of Operating Company	Boilers Make	Boilers Size	Boilers % Rating	Preheaters No.	Preheaters Date	Preheaters Make	Preheaters Elem'ts	Preheaters Surface	Pounds per Hour Gases	Pounds per Hour Air	Temperatures Entering Gas	Temperatures Entering Air	Temperatures Leaving Gas	Temperatures Leaving Air	Cleaning Method	Cleaning Frequency
Adirondack Power & Light Company—Amsterdam	B. & W.	19,830	***	3	1924	C. E.	90	11,700	191,200	178,300	429	80	279	241	***	***
Bosh Food Prod. Company Peoria, Illinois........	B. & W.	2,140	***	1	....	C. E.	10	810	4,500	4,500	550	70	310	310	***	***
Ohio Power Company, Philo, Ohio...........	B. & W.	14,090	***	4	....	C. E.	90	9,700	302,000	253,800	400	60	290	170	***	***
Ohio River Edison Co. Toronto, Ohio........	B. & W.	20,500	***	4	1925	C. E.	120	11,700	380,000	281,000	612	100	479	280	***	***
General Construction Co., Seward, Pennsylvania.	B. & W.	18,300	200	2	1924	C. E.	130	10,520	186,500	174,000	510	70	367	223	None	.....
Kansas City Power & Light Co., Kansas City......	Heine	12,740	***	1	....	C. E.	88	9,600	***	***	540	70	***	170	***	***
Narragansett Electric Light Co., Eddy Street	B. & W.	18,750	***	1	....	C. E.	92	14,100	80,300	63,500	475	70	294	302	***	***
Light Co., Eddy Street.	B. & W.	18,755	***	1	....	B. &. W. Tubular	...	14,961	149,000	139,000	535	80	347	291	Steam soot blowers	.....
General Electric Co., Philadelphia, Penna...	B. & W.	5,535	***	1	1924	B. & W. Plate	***	5,735	38,000	36,000	530	80	369	265	***	***
Houston Electric Co., Houston, Texas.......	B. & W.	19,844	***	1	1924	B. & W. Tubular	...	11,660	203,000	191,000	565	150	450	283	Hand brushing	***
Los Angeles Gas & Elec. Corp., Los Angeles.....	B. & W.	25,450	200	3	1925	B. & W. Tubular	...	23,025	208,600	196,000	557	70	358	300	Soot blowers	.....
Montaup Elec. Co., Fall River, Somerset Sta...	Stirl.	14,916	***	1	1925	Horizontal Tubular	...	10,514	137,000	128,000	387	70	295	175	Soot blowers	.....
New York Edison Co., Waterside, No. 2......	B. & W.	Two 6,500	200	1	1924	Thermix	...	12,100	105,000	105,000	450	70	278	252	Steam or air jets	***
Russell-Miller MillingCo., Grand Forks, N. D....	Water Tube	Two 2,500	***	1	1925	Thermix	...	2,160	23,400	*48,600	410	55	236	140	Hand cleaning	***
Phoenix Utility Co., Carolina Power Co., Moncure, N. C.......	B. H.	11,390	***	2	....	C. E.	75	6,075	217,000	205,000	680	125	530	283	***	***
Delaware County Eelctric Co., Chester, Penna...	Stirl.	14,217	***	1	1924	P. E. Plate	***	22,000	***	***	***	***	***	***	***	***
Chester, Penna.......	Stirl	14,217	***	1	1924	Ljungström	...	64,960	***	***	***	***	***	***	***	***
Chester, Penna.......	Stirl.	14,217	***	1	1924	B. & W. Tub	...	50,000	***	***	***	***	***	***	***	***

* Heated air in this installation used for industrial purposes.
*** Information not available.

the operation of the furnace, and it was very evident that with the continued increase of temperature to 300 deg. or even higher, a further improvement would be marked.

As to the maintenance of air preheaters, most of the experts were considering Eastern coal, which was low in sulphur, and which did not have to such a pronounced degree the objectionable characteristics of Illinois coal. His company's greatest trouble with economizers, and they had probably used their share of economizers, had been with the sulphur pyrite deposit which came from flue gas. The coal originally had 4 or 5 per cent of sulphur, and at temperatures at which economizers were operated the corrosion took place very fast and the maintenance was unusually high.

On top of this, the deposit on the tubes themselves was of such a nature that it did not fall off. It could not be blown off or scraped off. The only successful means they had found so far was to wash it off, and it took a lot of water. Just how they would clean air preheaters he did not know. From their experience so far, the deposit in the air preheaters was very similar to that in the economizers. It could not be blown off; it would not fall off; it retarded the heat transfer and upset all plans. So far they had had to wash it off, and just how long these preheaters were going to last under such conditions they did not know. Just what the maintenance would be was also unknown, but the maintenance with Illinois coal would play a very important part in the utilization of air preheaters as it had with economizers.

Francis Hodgkinson[1] said that he had had the pleasure of follow-

[1] Ch. Engr., Westinghouse Elec. & Mfg. Co., So. Philadelphia Sub. Sta., Philadelphia, Pa. Mem. A.S.M.E.

LATIONS ACTUALLY OPERATING

Gain in Efficiency: Heat added to Air	Gain in Efficiency: Other Causes	Kind of Coal	Heat Value	Proximate Analysis: Vol.	F. Carb.	Ash	Moist	Sulph.	Type Stoker	Type Pulv. Fuel	Type Furnace	Source of Data
1.6	***	Illinois	11,800	39	42.7	18.3	18.	4.4	Coxe	....	Solid	Observations } Commonwealth Edison Co.
1.3	***	Illinois	11,800	39	42.7	18.3	18.	4.4	B. & W.	....	Solid	Observations } B. & W. Company Design
....	...	Pitts. Bit.	13,500	34.75	53.76	8.82	2.65	1.23	Underfeed	....	Solid	Design } Dwight P. Robinson Co.
....	...	Pitts. Bit.	13,500	34.75	53.76	8.82	2.65	1.23	Underfeed	....	Solid	Design } Dwight P. Robinson Co.
....	...	Pitts. Bit.	13,500	34.75	53.76	8.82	2.65	1.23	....	Lopulco	Air Cooled	Design } Dwight P. Robinson Co.
		Pitts. Bit.	13,300	34.75	53.76	8.82	2.65	1.23	....	Lopulco	Air Cooled	Observations } Dwight P. Robinson Co.
***	***	Illinois	11,500	32.	***	***	8.0	2.0	Type E	....	Solid Wall	Design—Comb. Eng. Corp.
***	***	Washed Pea	11,104	20.18	52.87	19.9	7.05	***	Hand Fired	....	***	Test—Prat-Daniel Co.
2.49	***	50% Scotch 50% York	11,052	29.42	50.75	7.79	12.04	1.33	Chain Grate		Solid Wall	Test—B. & W. Co., Ltd., London
2.70	***	....	11,052	29.42	50.75	7.79	12.04	1.33	Chain Grate	....	Solid Wall	" " " " " "
3.5	***	Lancashire Slack	***	28.12	46.88	13.44	11.56	1.44	Chain Grate	....	Solid Wall	Test—B. & W. Co., Ltd., London
7.7	***	Small Coal	***	30.57	48.48	17.98	2.97	1.16	Chain Grate	....	Solid Wall	Test—B. & W. Co., Ltd., London
10.4	***	Gedley Wash Singles	10,850	34.30	58.35	***	15.88	***	Chain Grate	....	***	Design—James Howden & Company
2.8	...	Bituminous	12,670	17.8	75.5	9.3	5.3	...	Riley	....	Solid Wall	Test } Union d'Electricité, Paris
***	***	Bituminous	***	12.0	70.0	8.00	10.0	1.0	Chain Grate	....	Solid Wall	Test } Union d'Electricité, Paris
***	***	***	***	***	***	***	***	***	***	***	***	Test—Prat-Daniel Co., Paris
18.0	1.2	Wigan Slack	***	27.3	50.6	***	6.4	2.75	Hand Fired	......	***	Test—Howden Ljungström Co., Sweden
***	***	Bituminous	***	22.5	65.0	10.2	2.3	1.83	Underfeed	....	Air Cooled	Design—Connery & Company
***	***	***	***	24.45	64.25	8.29	3.01	1.18	Underfeed	....	Solid	.... Philadelphia Electric Co.
***	***	***	***	24.45	64.25	8.29	3.01	1.18	Underfeed	....	Solid	
***	***	Bituminous	11,300	28.66	***	9.9	11.5	***	Type E	....	***	Test—Underfeed Stoker Co., London
***	***	Hillhouse Pea	12,487	31.4	57.6	11.0	7.47	***	USCO"A"	....	***	Test—Underfeed Stoker Co., London
***	***	***	11,910	30.27	***	***	***	***	USCO"B5"	....	....	Test—Underfeed Stoker Co., London
***	***	Scotch Pea	10,980	25.82	51.13	8.43	14.62	***	USCO"A"	....	....	Test—Underfeed Stoker Co., London

OF INSTALLATION OR ON ORDER

Gain in Efficiency: Heat added to Air	Gain in Efficiency: Other Causes	Kind of Coal	Heat Value	Proximate Analysis: Vol.	F. Carb.	Ash	Moist	Sulph.	Type Stoker	Type Pulv. Fuel	Type Furnaces	Source of Data
***	***	Anth.	11,500	5.6	***	***	10.0	***	Coxe	....	Solid Wall	Design—Comb. Eng. Co.
***	***	***	***	***	***	***	***	***	***	***	***	Design—Comb. Eng. Co.
***	***	Pitts. Bit.	11,600	36.0	43.0	***	4.0	5.0	***	Coxe	Solid Wall	Design—Comb. Eng. Co.
***	***	Pitts. No. 8	***	***	***	***	***	***	***	Lopulco	Hollow Wall	Design—Comb. Eng. Co.
***	***	Penna. Bit.	13,800	18.0	71.75	10.00	0.25	2.0	Underfeed	....	Solid Wall	Design—Dwight P. Robinson Co.
***	***	Ill. Bit.	9,770	***	45.08	***	5.0	4.12	Coxe	....	Solid Wall	Design—Comb. Eng. Co.
***	***	W. Va. Bit.	14,740	21.5	72.5	6.00	2.00	0.64	....	Yes	Water Cooled	Design—Comb. Eng. Co.
4.7	***	W. Va. Bit.	14,740	21.5	72.5	6.00	2.00	0.64	....	Yes	Water Cooled	Design—Comb. Eng. Co.
3.6%	***	Oil	***	***	***	***	***	***	....	....	Solid Wall	Design—Babcox & Wilcox, New York
2.6%	***	Oil	***	***	***	***	***	***	....	....	Air Cooled	Design—Babcox & Wilcox, New York
4.5%	***	Oil	***	***	***	***	***	***	....	....	Air Cooled	Design—Dwight P. Robinson & Co
2.1	***	Oil	***	***	***	***	***	***	....	....	Air Cooled	Design—Babcox & Wilcox, New York
***	***	W. Va. Bit.	***	***	***	***	***	***	Underfeed	....	Solid	Design—Prat-Daniel Co.
***	***	Pocahontas Screenings	14,000	***	***	***	***	***	McClave Grate	....	***	Design—Prat-Daniel Co.
***	***	Pocahontas	13,768	15.87	71.39	***	2.97	0.52	Underfeed	....	***	Design—Comb. Eng. Co.
***	***	***	***	24.45	64.25	8.29	3.01	1.18	Underfeed	....	Solid	Design—Philadelphia Electric Co.
***	***	***	***	24.45	64.25	8.29	3.01	1.18	Underfeed	....	Solid	
***	***	***	***	24.45	64.25	8.29	3.01	1.18	Underfeed	....	Solid	

ing reasonably closely the developments of Colfax. He had hoped that the author would tell the general results of what had been done there on the station as a whole. He had been informed that they were quite remarkable from the standpoint of the total overall heat consumption per kilowatt-hour.

The author had gone a little further than he believed had been done before in the number of feedwater heaters. He has installed four, progressively heating the feed. That unquestionably was an economical and good thing to do, and to put it in very common language, the steam that went through the turbine and was condensed in the feedwater heater worked in the turbine with an efficiency of something like 90 per cent instead of about 20 per cent when going on to the condenser. This left the perfectly obvious necessity of doing something with the gases leaving the boiler. What more natural thing was there to do than to preheat the air?

It seemed to Mr. Hodgkinson that the mechanical difficulties of the air preheater were much less than those of the economizer. Furthermore, he thought air temperatures could be reduced much lower with the air economizer than with the water economizer, because of the mechanical difficulties of putting cold water into the economizer.

He thought Mr. Clarke was to be very much congratulated in having been somewhat of a pioneer in this field, and in having done some real things in power-house economics.

C. W. Heller[1] said that after a period of run on his company's air preheaters up to three months, the slight sooty deposit, which was like blistered paint, could be removed by a slight movement

[1] Duquesne Light Co., Pittsburgh, Pa.

of the plate elements or a slight lancing. They were not experiencing any serious dropping off of the heat transfer of the elements. The results the author had given were from tests. Although they were not secured in daily operation, they no doubt could be secured if the boilers were operated at a good load factor.

G. E. Pfisterer[1] said that everything the author had said regarding economizers and air heaters applied particularly to the central station, where exact data could be obtained. From his own observation of both economizers and air preheaters it seemed that the fact had not been definitely settled that the air preheater would do the work without the economizer and that the economizer would do the work without the air preheater. He had had occasion recently to come in contact with a situation where it had been necessary to find out exactly what could be done with a combination of one or the other, or both. Of course it was pretty well determined in central-station work, but there were many industrial plants where it was not physically possible to make an installation of air preheaters without incurring a great first cost. Many plants that would like to put in air preheaters could not do it, but they ought not to be handicapped when they could install economizers. Progress in the direction of preheating air was advancing rapidly, but there was not enough definite information yet to define it as regarded industrial plants. There were many engineers operating industrial plants who would take that into account. The economizer situation was still alive, and the fact that there were high flue-gas temperatures in certain types of boilers operating under certain conditions made it necessary to find some way by which those plants need not suffer because of the high cost which the air preheater entailed.

C. A. Jacobsson[2] wrote that his company at the present time had in Europe and the United States altogether about 140 air preheaters in operation and under manufacture, and in addition to those mentioned in the paper had the following preheaters operating or under manufacture in the United States:

	Boilers		Air Preheaters	
	Size	No.	Surface	No.
In Operation				
International Paper Company:				
Piercefield, N. Y.	3000	6	14,600	6
Niagara Falls, N. Y.	3000	6	14,600	6
Berlin, N. Y.	5120	1	21,500	1
Norton Company	5000	2	21,500	1
On Order				
International Paper Co., Berlin, N. H.	5120	1	17,600	1
Long Island Light & Power Co	12,000	2	26,700	4
Narragansett Elec. Light Co	18,750	2	40,000	4
American Gas & Elec. Co	20,000	1	40,000	2
Canada Paper Co., Windsor Mills, P. Q., Canada	5000	1	26,700	1

As would be seen from this table, the preheaters already in operation were in smaller industrial plants, and as in such cases it was very difficult to get complete and reliable tests, his company was not giving any performance figures of them. The results thus far obtained in this country were not of special interest for larger installations. However, larger units were under manufacture, and the air preheaters for the Philadelphia Electric Company and the installation at the American Gas & Electric Company were to be tested out, probably during the middle of January, and of course these tests would be made in a very scientific manner and would be of great interest.

The author, Mr. Clarke, in closing, said that in reference to Mr. Kreisinger's discussion, time alone would tell whether flame travel was sufficiently reduced by preheating air to cut down furnace volume. He thought something would be done along that line.

In reference to Mr. Pigott's discussion, Mr. Clarke did not agree with him that it was more economical, better, or cheaper to bleed a house turbine than the main unit. Personally he did not believe that a house turbine had any place in the present steam cycle. It was so much more efficient to take auxiliary power from the main prime mover, and the ideal way would be to take it off the station bus. However, that was not safe. The addition of an auxiliary generator, which was being used in several cases, made an ideal combination for safety. The two electric circuits were absolutely isolated. Switching short-circuits and other disturbances in the lines did not get to the house circuits, and it made a cheap, reliable, and highly efficient combination.

[1] Western Mgr., Green Fuel Economizer Co., 37 W. Van Buren St., Chicago, Ill. Mem. A.S.M.E.

[2] Sales Manager, James Howden & Co. of America, Ltd., New York, N. Y.

He could not answer Mr. Caldwell's question as to about auxiliary power. It was a point not thought of sufficiently to determine definitely. All he could say was that on the first installation of Colfax the fan that had furnished the preheated air had also furnished the blast under the stoker. The total load on the fan was 11 in. of water instead of 7 in.

As to air leakage at Colfax, there had been considerable leakage not in the ducts but in the preheater itself. The type had since been modified to welded construction, and should be, and as far as could be found out, were, airtight.

In reference to what Mr. Bailey had said, Mr. Clarke believed that there were some real difficulties to be experienced in connection with coal such as the Illinois coal; how much air preheating it would stand and what the temperatures would be, would have to be found out by actual experience. He believed that some of Mr. Bailey's difficulties were due to carrying flue-gas temperature too low, which he did not consider justifiable at the price of coal.

As to maintenance in an air preheater, it should be possible to corrode or erode to paper thinness. There was very little difference in pressure across the plates. With air blowing through the preheater there was a maximum of five or ten inches, and a draft of an inch or two, depending on the conditions. The maintenance also should be more readily made. The steel plates could be easily handled. The question of welding was being handled efficiently today, and even with a large amount of erosion he would expect the maintenance to be considerably lower than in a pressure economizer.

In reference to Mr. Hodgkinson's question as to what had been done at Colfax on overall station efficiency, Mr. Clarke said that prior to the building of that station, the Duquesne Light Company had had a system load of 800,000,000 kw-hr. In 1924 the Colfax station had carried 800,000,000 kw-hr. The total coal consumption prior to the starting of Colfax had been 1,016,000 tons. To carry 800,000,000 kw-hr., the coal consumption at Colfax had been 564,000 tons. The coal bill had been almost cut in half. That was due, of course, to the building of a modern high-pressure station as against the moderate-pressure plant at Brunots Island. It gives an example of what benefits could be derived from making developments of that kind.

Two years ago this summer they had started a new development at Colfax. The station had had two 60,000-kw. units. The coal rate had been 18,500 to 19,000 B.t.u. The coal in pounds would be 1.45 per kw-hr., containing from 13,000 to 13,500 B.t.u. He had questioned seriously the advisability of changing the pressure in order to secure economies, so they had had to look elsewhere to get a heat rate comparable to what the art demanded at a reasonable cost. It had been decided to put in pulverized fuel, air preheaters, generator-air coolers, and a few other refinements, and their expectations had been more than gratified. Mr. Graves, the vice president and general manager, had sent the author a letter on January 10, giving a statement of the operating figures for December, 1924. It should be borne in mind that there was one new 30,000-kw. unit operating, together with the two 60,000-kw. units which were installed several years ago, and another one to go in service the last of January. With the station generating in December 2,800,000 kw-hr., high load factor, and with a boiler-room efficiency on an average of 78.4 per cent, the heat rate had been 17,860 B.t.u. per kw-hr. output on the station buses. The best day of that month it had been 17,100 and the worst day, a Sunday, 18,877. He had been in Pittsburgh the week before and the records for ten days of the month had been 16,900 B.t.u., approximately, on an average. The addition of another 30,000-kw. unit would lower those figures materially.

In reference to Mr. Pfisterer's comments, Mr. Clarke said that the survival of the fittest would tell whether air heaters or economizers or something else would be used for flue-gas heat reclamation. He only held a brief for the machine that did the most work for the dollar. He personally thought today that the air heater was that machine.

In connection with the Los Angeles installation, some very interesting calculations had been made. The station was located where oil was the principal fuel, the only fuel, in fact. The price a year ago last December had been 60 cents a barrel. Today he imagined it was between $1.25 and $1.50, with a possibility of going to $2 a

barrel. Calculations had been made with that end in view. Combinations of large economizers reducing the flue gas to 250 deg. had been made; combinations of two-stage air heaters to reduce the flue gas to the same point had been made; and combinations of economizers and air heaters to reduce the flue gas to the same temperature had been made. The same condition had been carried through on a flue-gas temperature of about 350 deg. It had been found that, considering investment cost, load factor, and oil cost that would be reached in the near future, the only thing to do from an economic point of view was to install air heaters to heat the air to 300 deg. final temperature, lowering the flue gas to somewhere in the neighborhood of 350 deg. The combination of air heaters and economizers had offered no advantages. It would have been tremendously expensive. It took about as large an air heater to add 100 deg. to the air at that low temperature as it did to add 200 deg. at the high.

Referring to Mr. Jacobsson's communication, Mr. Clarke said it was to be regretted that the Howden Company had not submitted the data given by Mr. Jacobsson at the time they had been requested to give full particulars as to their preheater installations, for their inclusion in the tables would have made the paper much more complete.

The Unit Coal-Pulverizing Plant and Its Operation

Descriptions of A Number of Some Installations—Advantages of the Unit System

By J. G. Coutant,[1] New York, N. Y.

There are between 400 to 500 boilers now being supplied with powdered fuel from unit pulverizers, which assures us that this method of firing boilers is not new, although it is only recently that it has received the stamp of approval by its being adopted in new central-power-station work.

Power House at Comines, France

The power house at Comines, near Lille, France, is among the newest of the large power stations of Europe and contains eight 10,760-sq. ft. B. & W. boilers with chain grates for burning low grades of fuel and four boilers with unit pulverizers furnished by La Combustion Rationnelle, Paris. Each of these boilers is served by two pulverizing units, each with a capacity of 4400 lb. per hr., with three burners for each pulverizer, so arranged that one pulverizer unit will be in operation at full capacity during normal operation, thus consuming the least amount of auxiliary power per ton of coal prepared and burned—about $1^1/_4$ per cent of the total fuel, based on 18,000 B.t.u. per kw-hr. The second pulverizer is for emergency and peak loads.

The chain-grate stokers have shown excellent results and only two to three per cent lower efficiency than that of the powdered-fuel units. The coal burned is fine, containing large amounts of dust, 9.2 per cent moisture, 19.2 per cent ash, and 14.4 per cent volatile.

The stokers are operated at their most economical rate of combustion and the fluctuating load is carried by the powdered-coal units that maintain 77 per cent boiler efficiency and 80 to 82 per cent with economizers.

The satisfactory and economical operation of the unit pulverizer during four years of continued service has warranted the Société L'Energie Electrique du Nord de la France in placing their fifth repeat order for such apparatus installed in the recent extensions to the Comines station. Fig. 1 shows a modern French boiler setting.

Central Station at Rouen

The boiler house at Rouen is equipped with B. & W. cross-drum boilers of 5000 sq. ft. of heating surface. All except five boilers are equipped with chain-grate stokers burning Cardiff coal which is received by steamer. Five of the boilers are equipped with unit pulverizers and are put in operation for peak-load periods twice daily for a duration of two hours, burning coal of the best quality.

Three years' operation has proven unit pulverizers to be the most flexible means for meeting sudden demands for steam, and for eliminating the excessive stand-by losses and fixed charges that would be incurred with stoker firing.

The fixed charges in this particular case have been reduced to a minimum, the stokers being removed one by one, parts being credited into stock and to apply on the cost of new pulverized-coal equipment, and the combustion chambers being built up from the basement floor as shown in Fig. 2. In this manner the plant has been brought to a higher state of efficiency, with a very small increase in capital investment.

Central Station at Wasquehal

The central power station at Wasquehal, France, one of the older stations, has 14 Niclausse boilers of 2050 sq. ft. heating surface; each pair of boilers is served by one turbo-pulverizer of 3300-lb. capacity.

The principal feature of the station is the firing of two boilers with one unit pulverizer that has been placed in the narrow firing

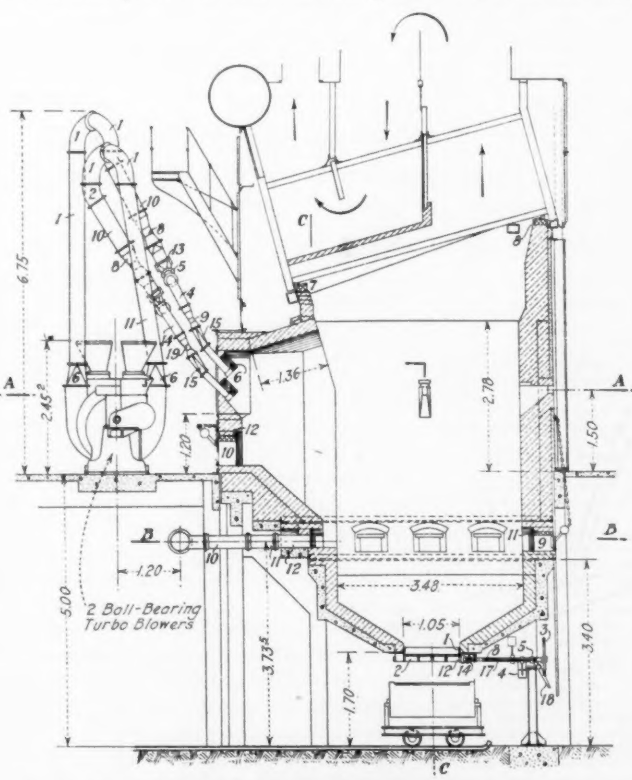

Fig. 1 Unit Pulverizer, Comines Station, near Lille, France

aisle; also showing that it is possible to equip old stations without changing boiler settings, coal-conveying machinery, or building, and at the same time increase the boiler capacity burning a variety of lower-grade coals.

Another feature is that no special design for combustion chambers with large volume nor complicated burner or feeder arrangements has been found necessary for the required steam capacity of boiler, as may be seen from Fig. 3.

[1] Furnace Engrg. Co., 5 Beekman St. Mem. A.S.M.E.

Presented at a joint meeting of the Cleveland Engineering Society and the Cleveland Sections of the American Society of Heating and Ventilating Engineers and The American Society of Mechanical Engineers, Cleveland, Ohio, Jan. 13, 1925. Contributed by the Cleveland Section of the A.S.M.E. Abridged.

THE TURBO-PULVERIZER

La Combustion Rationnelle, who have furnished the equipment for these three stations, have put in operation 160 turbo-pulverizers that serve 150 boilers having a total heating surface of 540,000 sq. ft.

The turbo-pulverizer will pulverize coal and lignite containing normally 5 per cent moisture, although no difficulty will be encountered when burning coal containing 10 to 14 per cent moisture. The greatest amount of moisture that the author has known in coal pulverized and burned by a unit pulverizer was 19.4 per cent, with a Bettington machine. The power consumption increases with the moisture content of the coal, and will average approximately 1½ to 2½ per cent of the total fuel burned.

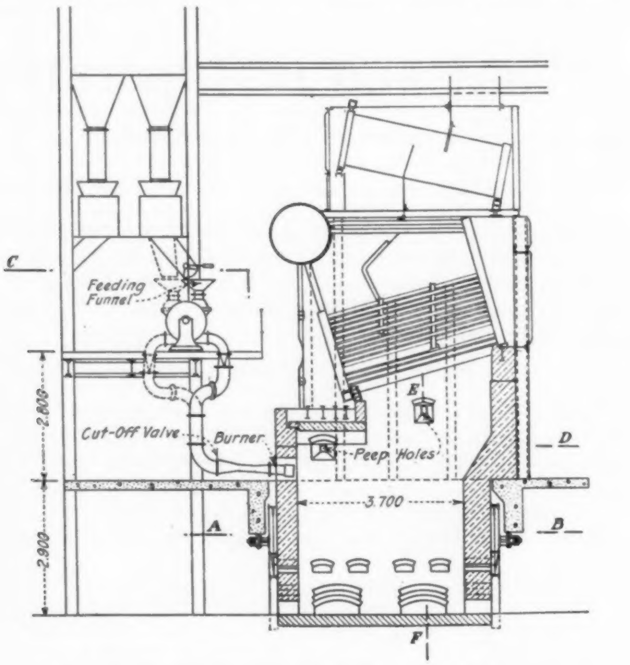

FIG. 2 UNIT PULVERIZER, ROUEN STATION, FRANCE

TABLE 1 BOILER TRIALS WITH UNIT SYSTEM OF COAL PULVERIZING

	Comines	Wasquehal	Rouen
Number of boilers	4	13	2
Type of boiler	B. & W.—C. D.	Niclausse	B. & W.—C. D.
Heating surface, sq. ft.	10760	2100	5380
Evaporation (rated normal), lb.	66120	....	26148
Evaporation (rated full), lb.	88160	....	31856
Superheater surface, sq. ft.	6671	1032	1442
Economizer	Green	....	B. & W.
Economizer surface, sq. ft.	8931	688	4035
Draft	Prat	Natural	Prat
Chimney height, ft.	100	....	55
Pulverizer	Rationelle turbo-pulverizer		
Pulverizers per boiler	2	½	2
Pulverizer speed, r.p.m.	1450	1450	1450
Pulverizer capacity, lb.	4400	2650	....
Burners per boiler	6	1	2
Burner inclination, deg.	30	30	10
Volume of furnace, cu. ft.	3988	....	1978
Date of trials	10–5–23	8–10–21	5–16–22
Steam pressure, lb. gage	285	215	224
Water to economizer, temp., deg. fahr.	111.2	113	60
Water to boiler, temp., deg. fahr.	204	210	197
Steam temp., deg. fahr.	599	599	539
Coal	Small bituminous		
Moisture, per cent	9.5	2	4
Ash, per cent	19.2	24	22.1
Volatile, per cent	14.4	29.6	18.4
Heating value (low), B.t.u. per lb.	10998	10440	11604
Water evaporated per sq. ft. per hr.	4.65	4.825	4.8
Boiler rating, per cent	168	175	180
Boiler and furnace efficiency, per cent	78.4	79.2	79.
Boiler, furnace and economizer efficiency, per cent	84.5	85.9	85.4

The turbo-pulverizer has three parts, the feeder, the pulverizer, and the exhauster. The feeder is a horizontal rotary table receiving the raw coal in pieces and dust, and delivering the pulverized fuel continuously at a rate determined by the feeder. The pulverizer rotor has a horizontal shaft on which are mounted several disks with paddles for pulverizing, and it is enclosed in a cylindrical case with compartments for each disk. The paddles pulverize the materials successively in each compartment. The exhauster, carried on the shaft with the other units but having a separate casing, draws the pulverized coal from one compartment to the other, and finally mixes it with sufficient air for delivery to the furnace.

There are many types of unit pulverizers on the market and some have attained remarkably good results, although it is difficult to find reliable data concerning the operation of such machines under working conditions.

It is conceded that the unit system can be installed for at least one-half the capital required for a storage system, as shown in Table 2, and that it will in all probability be lower than the cost of stokers. One naturally asks regarding the performance, power consumption per ton, fineness of pulverization, maximum moisture content, maintenance and floor space, as well as reliability and liability.

TABLE 2 RELATIVE COSTS OF STORAGE SYSTEM AND UNIT SYSTEM

Storage System[1]				Unit System[2]
Capacity, tons per day	Cost of equipment, dollars	Cost of building, dollars	Total cost, dollars	Total cost, dollars
100	50,985	10,700	61,685	10,500
200	67,980	12,500	80,480	21,000
300	81,376	14,750	96,126	31,500
400	96,305	15,300	101,605	41,500
500	109,901	16,000	125,901	49,000
600	124,630	17,500	142,130	58,000
700	139,359	18,500	157,859	67,000
800	154,480	19,500	173,980	76,000
900	167,684	20,500	188,184	86,500
1000	182,413	21,750	204,163	96,000

[1] Bureau of Mines Bulletin No. 217, p. 101.
[2] Furnace Engineering Co.

SIMPLEX UNIT PULVERIZER

The Furnace Engineering Company, in conjunction with the testing staff of the United Electric Light & Power Company, have conducted extensive tests with an 8000-lb. capacity Simplex unit pulverizer installed in connection with a 6300-sq. ft. boiler at the Sherman Creek Station, New York.

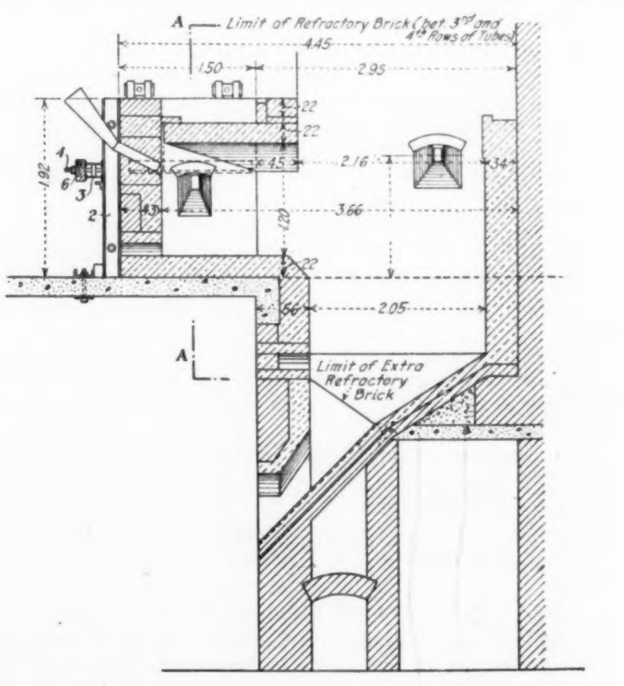

FIG. 3 UNIT PULVERIZER, WASQUEHAL, FRANCE

The Simplex unit involves a new method of pulverization. It pulverizes the fuel without drying and delivers the powdered coal at uniform maximum fineness to the furnace with a minimum power consumption, maintenance, and fixed charges that include libility and fire insurance. It consists of a coal crusher, pulverizer, and exhauster with pipe arrangement to boilers. A magnetic separator, usually furnished with the unit, first receives the coal from bunkers and removes all iron or steel therefrom before passing it to the crusher.

The coal arrives at the crusher in sizes of 4 in. and less, where it

is reduced in a small gyrating crusher to $^3/_{16}$-in. size and less; thus filling the feeder pockets at each revolution with a uniform quantity of coal that insures a constant rate of coal supply to the pulverizer. The function of this crusher is to provide a more uniform size of coal to the feeder, and to enable the delivery of powdered fuel to the furnace at a predetermined constant rate. On account of this constant rate of fuel supply to the furnace, it is possible to maintain furnace temperatures where desired at 2900 to 3100 deg. fahr., and for boilers the pulverizer will show efficiencies that are 3 to 6 per cent higher than those of other unit systems supplied with $1^1/_4$-in. and smaller coal.

The pulverizer consists mainly of a cylindrical casing with a hard steel lining in which paddles revolve to break up the coal into a powder. This casing is mounted on a bed plate and base, together with a motor or turbine.

The pulverizer operates at nearly twice the peripheral speed of the other types. An air separator of cast iron and steel ribs of considerable axial length is fitted to the casing between the revolving disks with paddles and constitutes the chief difference between the Simplex and the turbo-pulverizers.

FINENESS OF PULVERIZATION

The necessary fineness to which the coal must be pulverized depends to a large extent on the nature of the coal and the power required for grinding, which latter increases rapidly with the degree of fineness. It is desirable with storage systems to ascertain by experiment the degree of fineness that is necessary; such conditions, however, are not applicable to unit pulverizers, as they often are expected to pulverize coal containing 10 to 15 per cent of moisture and which materially affects the ignition temperatures and would delay the combustion of any coarse coal. It is therefore essential that with unit pulverizers the coal should be pulverized to the maximum fineness, thus requiring an efficient means of air separation. Results of tests are given in Table 3.

TABLE 3 FINENESS OF PULVERIZATION

Simplex unit pulverizer on pocohantas coal. Coal analysis (per cent): Moisture, $4^1/_2$; volatile, 18; fixed carbon, 71; ash, 6.5; sulphur, 1.35.

	Mesh per Linear in.	Wire Die	Opening width, in.	Openings per sq. in.
91% passing	100	0.0045	0.0055	10,000
85% passing	200	0.0021	0.0029	40,000
	300	0.0016	0.0017	90,000

FLEXIBILITY, MAINTENANCE AND POWER CONSUMPTION

The flexibility of boilers fired by the unit pulverizer is a remarkable achievement. Cold boilers have been put in operation at full steam capacity in 14 to 18 minutes from the time that a match was applied to the oil-soaked-rag torch held in front of burner. Likewise, boilers operating at 200 per cent rating, 6.9 lb. evaporation per sq. ft., have been raised to 300 to 350 per cent rating in one and one-half minutes.

The maintenance cost on the unit system should not be more than $1^1/_2$ to 2 cents per ton for bituminous coal. Parts subject to wear can be supplied under contract on a basis of 3 cents per ton of coal pulverized.

The power required to pulverize coal containing various quantities of moisture is shown in Table 4.

TABLE 4 POWER REQUIRED TO PULVERIZE COAL CONTAINING VARIOUS QUANTITIES OF MOISTURE

(Performance of 8000-lb. capacity Simplex unit)

Moisture in coal, per cent	Capacity, lb. per hr.	Approximate power consumed, kw-hr. per ton	Total for unit, kw-hr.
4	9000	14	63.0
6	8750	15	65.62
8	8400	16.25	68.25
10	8000	17.5	70.00

THE UNIT SYSTEM FOR CENTRAL-POWER-STATION WORK

It is only recently that the unit system has been considered for the firing of large boilers on account of the small capacities of such machines. A 4400-lb. machine has been developed in France which operates successfully with 10,860-sq. ft. boilers, and the American machine with a capacity of 8000 lb. per hr., installed at Sherman Creek, has pulverized and delivered to the boiler furnace 10,000 lb. per hr. There is no difficulty in building this same type of machine with a capacity of 20,000 lb. per hr.

In comparison with other means of burning fuel, the unit method of preparation and burning will be found the most economical from the standpoint of investment, maintenance, practicability, simplicity, etc. without noise, vibrations, and dust nuisances. It is recommended that the various items of other methods of firing should be compared with the unit method, to arrive at the cost of steam production.

Progress in the Art of Power Development

BY NEVIN E. FUNK,[1] PHILADELPHIA, PA.

DURING the year 1924 there were put in service nine power plants which had been designed for an ultimate capacity of 250,000 kva. or over. In addition to these ten more plants of like capacity are in the process of construction, making a total of nineteen plants ranging from 250,000 kva. to 750,000 kva., and of the nineteen there are three of 600,000 kva. capacity or over, which as planned are individually the largest power developments in the world.

As at present planned, the steam pressures range from 400 to 600 lbs., with steam temperatures of from 700 to 750 deg. fahr.

The possibilities of high pressures have been fairly discussed and several installations of 1200-lb. boilers and turbines have been laid out, although none of these high-pressure plants are in operation.

Except for a few isolated cases there has been no particular tendency toward increasing the size of boiler units, which vary from 1500 to 2500 boiler-horsepower capacity. Many modifications in furnace and stoker design have been tried and many of the new plants are installing air preheaters.

The progress in fuel-burning equipment was very thoroughly summarized in the Report on Developments in Fuel Engineering and Research during 1924 by Mr. H. W. Brooks, Fuel Engineer of the U. S. Bureau of Mines, for the Fuels Division of The American Society of Mechanical Engineers, which was printed in the February issue of MECHANICAL ENGINEERING, p. 145, and in the interest of conservation of time and space the Power Division refers to this report for the outstanding improvements in the power-plant boiler room.

The mercury boiler and mercury turbine of 1800 kw. capacity installed at Hartford, Conn., and which were referred to in Mr. Lawrence's résumé last year, have been in satisfactory commercial operation, although as yet, due to the newness of this particular phase of the art, no conclusive operating information is available. The fact remains that this apparatus has functioned commercially, with only those troubles that might be expected from new apparatus that has not gone through the rigors of daily service.

The single-shaft steam turbine has been developed in sizes of 50,000 kw. at 1200 r.p.m. and 50,000 kw. at 1800 r.p.m.

Practically all the new stations are arranging for stage bleeding of their main turbine units for improving the heat balance of the turbine end of the heat cycle. This has necessitated a much more extensive use of electric drive than in the past, although there has been some slight tendency to revert to the use of steam-driven auxiliaries.

A few of the stations referred to above have been arranged for the reheat cycle, although due to the complication and size of steam piping this does not seem to be in such very high favor.

Nothing particularly new has developed in turbine auxiliaries or condensers.

In the hydraulic field nothing has been done to surpass the installation of the 70,000-hp. hydraulic turbine placed in operation at Niagara Falls.

The increasing size of power systems has made possible the development of streams for peak-load supply which have not been available for base-load purposes, and the continued improvement in the design of full-automatic stations of small sizes has permitted the economical development of small streams whose energy otherwise has not been available.

[1] Operating Engineer, Philadelphia Electric Co. Past-Chairman of A.S.M.E. Power Division. Mem. A.S.M.E.

Large Steam Turbines

A Discussion of Their Economy and Reliability and of the Present Trend in Design

By FRANCIS HODGKINSON,[1] PHILADELPHIA, PA.

UNTIL now, I have confined myself to past and existing practice in turbine design.[2] My remarks would not be complete did I not refer to the present trend of design. It is well known that the steam turbine of large size, under reasonably favorable conditions, has reached a high degree of efficiency. Eighty per cent or more of what is theoretically possible from the expansion of the steam is today available at the shaft of the turbine. I feel, however, that the turbine designer has by no means reached the end of his tether and that there remains much that may be done. Certainly greater reliability must be secured, and there still remains a modicum of attainment in efficiency. The percentage is small, it is true, but remember that in a base-load station of, say, 100,000 kw. capacity with 75 per cent load factor, a 1 per cent real gain in steam consumption (not necessarily that in a contract warranty) represents a capitalization for fuel alone of \$175,000, based on a fifteen-year life, 6 per cent interest, and \$4.50 per ton cost of fuel. That refers to the prime mover alone, but I think it is still true, though to a less degree than formerly, that it is not the efficiency of the prime mover that spells low cost of power. Highly efficient prime movers contribute little as compared with eternal vigilance in connection with boiler-house problems and matters of heat balance, feed heating, etc., in which subjects, however, great progress has been made of late.

Undoubtedly every designer, purchaser, or operator of a prime mover must fully subscribe to the doctrine of "Reliability first, economy second." Obviously some modicum of present efficiency had best be sacrificed if a greater degree of reliability cannot be secured in any other way, and there are those, indeed, who hold that this would be a wise course to pursue today. I venture to say that it is not an unusual experience for the designer of prime movers to find in his dealings with purchasing engineers that the latter have a dual personality. The designer, to begin with, is coerced to produce a machine of the highest possible economy, and to attain this he has sometimes subscribed to details perhaps not altogether well tried. With the best intentions and with full recognition of the doctrine of "Reliability first, economy second," he runs near the danger line, and this combined with some unfortunate operating circumstance, causes outages in the operation of this prime mover. It is then he discovers the dual personality of the purchasing engineer, when he is asked what the purchasing engineer cares about one or two per cent of efficiency as compared with reliability. As a matter of fact, the purchasing engineer is correct in both phases of this dual personality.

Frankly, I personally would be sorry if designers were to depreciate the efficiency of their machines. They must, and can, secure increased reliability without this, for I hold that greater reliability is to be secured at the same time as a moderate gain in efficiency. Of course, high efficiency is to be secured with turbines designed for low leaving loss and, as I think it can be shown, with many stages, and while elaboration in design affects cost, I am not losing sight of fixed charges in my thoughts on these matters.

It seems to me that turbine practice in Europe is in a transitory stage, and that the changes are well worthy of study at our hands. European engineers are reaching out for higher efficiencies, and one must consider in the doing of it to what degree reliability may be imperiled and to what degree we on this side may profit thereby. Are their standards of reliability lower than ours? I can't answer that question. My impression is that utility companies carry more spare parts there than here, and do not expect the manufacturer to carry an insurance policy for them in this regard.

[1] Ch. Engr., Westinghouse Elec. & Mfg. Co., South Philadelphia Sta. Mem. A.S.M.E.

[2] The author refers to a résumé of a paper which he presented at the World Power Conference, and which dealt with types of turbines and features of design. See MECHANICAL ENGINEERING, October, 1924, p. 628.

Abridgment of an address delivered at the Second Annual Power Meeting, Chicago, Ill., Jan. 14 and 15, 1925, of the Chicago Section of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Tendencies in Design

I am sure all of us will recognize that able designing is not limited to this side of the Atlantic. This is amply shown by the purchase by one of the greatest public-utility companies of this city, and of the world, of a large and important machine—already referred to—a conception of a distinguished British engineer.

Some few years ago we were told of high efficiencies being at least guaranteed with high-velocity high-pressure elements, resulting in turbines of large capacities at given speeds with few stages—in instances as low as eight single-row stages—these being in some cases entirely of impulse type, and in others, combinations of impulse and reaction types. In spite of some recorded tests to the contrary, results with this type of machine have been disappointing, and designers, led by the classic experiments carried out by the Beama on nozzles, have come to the realization, long felt by at least some engineers in this country, that the best economy is to be secured with high-pressure elements running at low speeds. This is obviously so for reasons other than the somewhat abstruse ones indicated by the Beama tests, for, with a given steam flow, larger nozzle and blade passages may be employed, involving lesser leakage ratios and lower disk friction—all these things conducing to higher efficiency. The development of this thought—of a turbine of many stages in the high-pressure zone—has led many European designers to turbines of the tandem-compound principle, at least for their machines of maximum capacity at given speeds, in order to secure greater mechanical rigidity of the small shaft and many stages of the high-pressure portion, and to maintain fine clearances.

We have heard a good deal lately about the activities of the Erste-Brünner Maschinenfabrik and their exploitation of machines of a design based on the thought of high-pressure elements operated at low velocity. Remarkable results were secured with a 2300-kw. non-condensing machine adapted for service where exhaust steam at some pressure above atmospheric was needed for some industrial process. Authentic tests by Dr. Stodola showed an overall efficiency of the turbine alone of 82.4 per cent. It is obvious that such a turbine compounded with low-pressure elements would be a step in advance for a complete condensing power-house unit. The Erste-Brünner concern has now secured a number of licensees, particularly in Germany, and at least one in Holland, who are offering machines of this type, in fact, going apparently to the extreme in the matter of tandem-compounded cylinders. In one case a 50,000-kw. machine was lately offered in four tandem cylinders—one high-pressure, one intermediate, and two single-flow low-pressure elements to operate at 1500 r.p.m. It is to operate with a pressure of 357 lb. per sq. in., 660 deg. fahr. total temperature, and 29 in. vacuum, and a steam consumption of 8.11 lb. per kw-hr. is expected.

At the World Power Conference, C. F. Stork, of the Gebrüder-Stork Co., of Holland, in referring to their adoption of the Erste-Brünner idea, says in this connection:

> The keen competition has resulted in a struggle of the various turbine builders to show low steam-consumption figures, and it can hardly be denied that every single one of the designs that has been applied in order to obtain these figures has been made at the expense of the safety of working. This is the reason why, in the course of 1923, it was decided to design and build a turbine on entirely new principles.

This company was building a machine—perhaps now already built—which was described at the World Power Conference, of 16,000 kw., to operate with 456 lb. pressure, 750 deg. fahr. temperature, and 69 deg. fahr. temperature of cooling water, on which 8.44 lb. per kw-hr. has been guaranteed, which corresponds to an overall efficiency of 86 per cent for the turbine alone. I do not doubt that designers have been led to this extreme multiplicity of cylinders for the reasons stated by Mr. Stork—for the sake of increased reliability, securing rigidity with small-diameter shafts, and to enable them to operate with the interstage labyrinths with minimum clearance. I have been told, but cannot vouch for the truth, that axial clear-

ances in these turbines between blades and nozzles approximate 0.005 in. Fine clearances at this point are of course conducive to efficiency. It must not be lost sight of that there are losses incidental to taking out steam from one cylinder by means of a pipe and admitting it to another. Notwithstanding this, however, excellent results will no doubt be secured with machines built on these lines, and a number of manufacturers, licensees and otherwise, are subscribing to this principle and their later important machines are being arranged as tandem-compound machines.

The adoption of the one-speed coupled-tandem turbine is a reversion to the practice of both Parsons and Westinghouse of twenty-five years ago. With the relatively low rotative speeds of that day, I doubt whether much higher efficiency could have been secured in any other way and the machines built, though costly, were about as reliable as any today. Conditions, however, have changed in the respect of higher vacuum, and more particularly, higher speed of generators, as I have previously stated. It would seem, however, that the British have somewhat outstripped us in generator speeds inasmuch as 20,000-kw. single generators at 3000 r.p.m. have been constructed. One must not be misled, however, for there are differences in the practices of the two countries in the respect of relation of field strength to armature strength. The inherent voltage regulation is wider in their practice than in ours.

Of course, the principles of compounded turbines that I have been talking about, whether one-speed tandem-coupled, two-speed tandem-uncoupled, or two-speed cross-compounds, are applicable to impulse and reaction turbines alike. By such means higher efficiencies may be secured, I believe from 6 to 7 per cent, if appropriate low blade speeds are selected for the high-pressure elements and the low-pressure blades are designed for low enough leaving loss and between these there are enough stages to provide appropriate velocity ratios. The reliability will be increased to a greater or lesser degree according to the particular construction employed.

I need hardly say to many of you—and it is clear from the foregoing—that I personally have for many years advocated the cross-compounding of large turbines, for two particular reasons, most of which have been stated. The one that by operating the low-pressure element at relatively low speed, any last-row blade area can be employed, and hence any degree of low terminal loss secured. Simple blade constructions, involving any degree of low stress desired, may be employed. The high-pressure element of course will operate at a higher synchronous speed selected to give the highest efficiency with the steam volumes involved. The second reason for all the above is that there is added a real modicum of reliability by virtue of the greater simplicity and the lesser size of the two independent structures, and the lesser temperature range and heat drop to be reckoned with.

The large-capacity high-speed turbine generator of today is no small problem of design, and it may be greatly relieved by the two-speed-compound-turbine principle.

In the case of single-speed turbines (tandem-compound or single-cylinder) there seems to be a tendency in Europe, which I think should be followed here, of purchaser and manufacturer alike concentrating on and employing the maximum-capacity turbine at each of the available synchronous speeds, their best machines being built only in a limited number of sizes. Do not misunderstand me in this. I do not refer to machines where high capacity is secured at the expense of increased terminal loss, but to machines with design constants based on appropriate leaving losses, velocities of elements, and velocity ratios. At any given speed it is the least costly per kilowatt if similar design constants are employed, unless great cost is incurred in materials and construction for the purpose of securing a high rotative speed difficult of attainment. It is therefore the machine on which the most money can be spent in the minor details that tends to reliability and efficiency.

Other causes besides generator design have contributed to the reduction of steam consumption of all types of turbines. The higher speed permits reduced leakage and higher design constants such as velocity ratio without as much compromise for mechanical reasons. Higher vacuum has brought about increased cost of the extreme low-pressure portion of the turbine. Higher pressures and superheats have contributed greatly to better performance, but have added to intrinsic costs not only on account of the greater number of turbine elements to accomodate the increased heat drop but also because of more costly materials due to the higher temperatures. Every step in performance has resulted in higher intrinsic value, except where an increase of r.p.m. has been possible. Fortunately, there has been development of mechanical processes, so that actual costs have not increased in the same ratio as intrinsic values.

Higher Steam Pressures

As I have said before, the production of cheap power is not dependent on the turbine alone. There is a further possible improvement in the use of higher steam pressures. The gain due to bleeding the turbine for heating feed increases with the higher pressures. With three stages of heating it is approximately from $5^1/_2$ per cent at 300 lb. to 7 per cent at 1100 lb. Extra high steam pressures render the compounding of turbines more than ever desirable because of the greater heat drop. None of us know much about the use of high pressures. We have fair knowledge of the efficiency of turbines designed to operate with moderately high pressures—up to 1200 lb.—but we know little of the mechanical behavior of the steam in the turbine. It is not certain that this high-density steam will not be quite erosive. At all events, some turbines in Europe that have operated with 450 lb. have experienced quite serious deterioration of the high-pressure portion. It happens, however, that the steam in this instance is dirty and carries considerable foreign matter. Whether the difficulty is entirely attributable to this fact is not certain. Be this as it may, it is another suggestion pointing to the desirability of high-pressure elements of low velocity for such applications. We shall know more of this shortly. There will be the Crawford Ave. Station with 550 lb. pressure. In the Weymouth Station of the Boston Edison Co. an admirable experiment is being carried out of installing a 1200-lb. boiler and turbine exhausting into what is normally the high-pressure steam line in the power plant.

I think the desirability of a plant permanently arranged in this latter manner has been suggested where extra high-pressure turbines and boilers in combination with certain normal-pressure turbines would carry the base load and additional normal-pressure turbines and boilers placed in service on peaks. Such a scheme would seem to have much to commend it from the standpoint of economics.

Hitherto reheating has always been considered in connection with the operation of turbines designed for extra high steam pressure. Some engineers, I believe, have felt that reheaters are a necessary concomitant of extra high steam pressures because of the injurious effect of the high moisture content of the steam at the lower ranges of expansion. I never felt that this is true if stage feedwater heating means are well carried out and kept in service and the turbine arranged so that the maximum degree of water condensed during the expansion may be drawn to the heaters. The use of reheaters involves considerable complexity, not only because of taking steam from the turbine system to a place where it may be reheated and brought back again, but because of complication to the regulating mechanism of the turbine. In this connection it must be noted that there is little thermal advantage due to this reheating if the reheaters cannot be arranged for a small pressure drop, so I feel that when going to higher pressures, serious attempts will be made to eliminate the reheater for the reasons just stated and the further one of cost.

So far as concerns the economic gain due to the use of high steam pressure, you will find many opinions. I showed in my World Power Conference paper that it is to be expected that the efficiency of the turbine system such as was described, operating with 700 deg. total temperature and without reheating, will be from 80.8 per cent efficiency ratio for 300 lb. pressure to about 79.4 for 1200 lb. This would mean a saving of steam consumption of 12 per cent, and therefore about 12.8 per cent less B.t.u. in the steam supplied, which does not take cognizance of reheating or stage feedwater heating—which latter, as I said, is more valuable as higher pressures are reached.

Sir Charles Parsons in his paper, in the case of turbines designed for 750 deg. fahr. total temperature and 29 in. vacuum, predicts that the gain over 250 lb. pressure will be:

5.45 per cent for 500 lb.	13.82 per cent for 1500 lb.
10.08 per cent for 1000 lb.	15.9 per cent for 2000 lb.

In this instance he has included reheating and stage feedwater heating, as well as allowance for slightly lower boiler-plant efficiency at the higher pressures.

Mr. V. Nordström, of Sweden, predicts in the case of 750 deg. fahr. total temperature, and 29 in. vacuum that the fuel saving over 285 lb. pressure will be:

10 per cent for 710 lb. 11.5 per cent for 1420 lb.

So far as the attitude of turbine designers is concerned, I believe none of them either here or abroad will hold back in producing steam-turbine combinations capable of operating at any of the high pressures thus far contemplated, and furthermore will produce them with ultimate success. I would say that generally, in Europe, all engineers are subscribing to extra high pressures, but I think they regard 750 deg. fahr. total temperature as high enough for materials at present commercially available.

There are many points regarding details of design applicable to all types of turbines whereby improvements may be made, which time does not permit me to discuss. I hope that, because of increasing fuel costs, we in this country will strive for higher efficiencies, keeping before us the words of the doctrine I have talked about, but with RELIABILITY in larger type than Efficiency.

Discussion

A. B. CLARK[1] said that the author had mentioned the fact that reheating had been tried some time ago. About 1900, reheating was to have been tried on a machine of about 8000 kw. capacity, but before it was actually installed it was decided to add some impulse blades to the machine with the idea of getting as much benefit as reheating would have given. Unfortunately, the impulse element did not work out as expected and the whole thing was a failure. The reheater was not put in. Had the machine been installed as originally planned, something might have come of it.

H. C. Heaton[1] said that end tightening was employed on a Parsons-type machine at Waukegan, Ill.; his firm had had several experiences with severe vibration due to factors entirely disconnected with the subject in hand, and he might say that in no instance had they experienced the slightest trouble due to radial contact of the rotating parts. Those vibrations were of such magnitude that he was sure that without end tightening they would have been disastrous to an ordinary type of reaction machine, so personally he subscribed heartily to the principle.

The principal troubles they had experienced in the operation of all of their turbines had been due to what he called "warping" or displacement of the stationary member. It was occasionally due to warping of the rotor, but that of course resulted in a slight eccentricity of the movement which brought it into contact with the stationary blades. That had in many cases caused a heating of the rotor which was accumulative. The more a machine ran under such conditions, the hotter it got. The thing to attack most forcibly was the assurance that machines would not come in contact.

They had one type of trouble not associated with the turbine proper, namely, generator trouble. He did not think that generator construction had progressed in parallel with turbine construction because they had encountered certain troubles in the last few years that might easily have been avoided had they profited by the lessons of several years ago.

[1] Engr., Sargent & Lundy, Edison Bldg., Chicago, Ill. Mem. A.S.M.E.

[1] M.E., Sargent & Lundy, Rm. 1412, 72 W. Adams St., Chicago, Ill. Mem. A.S.M.E.

Turbine- and Boiler-Room Auxiliaries[2]

Requirements of Auxiliaries for Reliability—Variable-Speed Drives—Types of Motors—Effect of Availability of Main Unit on Auxiliaries

BY G. G. BELL,[3] PITTSBURGH, PA.

THIS paper deals principally with alternating-current motors for driving all but a few of the smaller power-station auxiliaries which require the greatest range of speed and fine adjustment. Its justification is that by far the greater part of the large stations are installing alternating-current motors for this purpose. One of the latest stations to be built has decided to install steam-driven auxiliaries throughout, and claims expected efficiencies comparable with that obtained by heating the feedwater by bleeding the main unit and operating motor-driven pumps.

REQUIREMENTS OF VARIOUS AUXILIARIES TO FURNISH RELIABLE SERVICE

Exciters. Some interruption to all auxiliaries with the exception of the exciter is permissible, and for this the most reliable type of drive is essential. The majority of the plants equip their main units with direct-connected exciters, and provide relay excitation from motor-generator sets or duplex-driven units. The majority of those plants which do not have direct-connected exciters have duplex-driven units. Experience indicates that either type of equipment gives very reliable service. Automatic throw-over has been provided in some cases and has worked satisfactorily.

The paralleling of steam-turbine-driven and motor-driven generator sets has caused trouble, as a result of motoring of the steam-driven set. Apparently if separate exciter sets are installed in the plant the reliability of such sets is increased if they are provided with an alternating-current motor for driving, which will act as a brake in case there is any tendency for the set to be motorized and overspeed.

Circulating Pumps. A very short interruption is permissible with circulating pumps; however, in case the interruption is long enough for the condenser to become vapor-bound, the length of time to get the unit back into service may be much longer than if there is a failure of the excitation. For this reason it is essential that at all times some water be kept flowing through the condenser. There can be a very considerable variation in the amount of flow without a material reduction in capacity. This, however, may appreciably affect the efficiency of the unit for a short time.

In most stations equipped with electrically driven auxiliaries, duplicate pumps and duplicate sources of power are provided; and in some cases one circulating pump has a duplex drive as well. Where duplex drives are not provided the pumps are generally both driven from the most reliable source of power, or at least one pump is operated from it.

If a more reliable type of service is required than can be furnished by two motor-driven circulating pumps supplied from two different sources of power, we should probably consider the installation of a duplex drive on one of the pumps. On account of the slow speed, such a unit would undoubtedly have to be gear-driven; and in that case it might be advisable to install a magnetic clutch, which could be arranged to operate when the speed of the pump fell a certain per cent below normal. However, our experience has not indicated that such an expenditure is warranted.

Boiler-Feed Pumps. The failure of an adequate supply of water for the boilers would cause serious damage to life and property, so in all large stations built recently at least a duplicate set of pumps are installed, and in some of the initial sections of large stations, greater leeway still has been provided. However, unlike excitation and circulating water, a short interruption to boiler feedwater is not serious, especially if caused by power-supply failure, as in that case the boiler auxiliaries would also likely fail. With

[2] Presented at the Second Annual Power Meeting, Chicago, Ill., Jan. 14 and 15, 1925, of the Chicago Section of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged. The first part of the original paper dealt with sources of alternating current for auxiliary drive.

[3] Mgr., Power Development, West Penn Power Co,

large steam drums, even with boilers operating at high ratings, there is a water supply for several minutes, so that has led to a more general use of electrically driven boiler-feed pumps, adequately protected by steam-driven pumps. A variation in one of the gage glasses at Springdale of 1 ft. would correspond to a lessening of the water in the boiler by 11,000 lb., provided that the lowering of the water in the gage glass represents a similar solid body of water in the drum. This corresponds to between four and five minutes' operation of the boiler at the ordinary maximum rating.

Condensate and Air Pumps. The service obtained from motor-driven condensate and air pumps has been satisfactory. Duplicate condensate pumps are usually installed, and if these are each driven from a different source of power they should give reliable service, considering the satisfactory manner in which the condenser will continue to function for a few minutes without the condensate pump running. The quite general use of the steam ejector for removing the air has furnished the simplest and most reliable form of apparatus and one to which there should be no objection from the standpoint of service.

Boiler-Room Auxiliaries

Stoker and Clinker-Grinder Drives. A short interruption to the stoker drive and quite a long interruption to a clinker-grinder drive are permissible, so service from house transformers should be satisfactory.

Fan Drives. House transformers should be a satisfactory source of supply for fans if an emergency source of supply is provided. In fact, there is some advantage in having the fans and stokers stop automatically if the load on the main unit is lost. The matter of reëstablishing service on these units will be discussed later when types of motors are under consideration.

Powdered-Fuel Drives. One peculiarity of the powdered-fuel boiler is the rate at which the steam output will vary when the amount of coal is increased or decreased, provided there is sufficient air present for proper combustion. In the indirect method of firing this means that special attention must be paid to the motor drives for the feeders, to guarantee them a reliable source of power. The amount of power required, however, is small, and in order to get the required speed variation the feeders are usually driven by direct-current motors. If the direct current is produced by motor-generator sets, these should be driven by the most reliable source of alternating current in the power plant, and should preferably have two sources of power. The primary air supply should also have a like reliable supply of current. The power required for it is relatively small; and in case of failure of the primary air, there is some danger of feeders clogging up. In most plants this is taken care of by installing steam jets. These steam jets are opened after the feeders are shut down. The feeders are then started operating again, and the jets furnish enough vacuum to transport the coal successfully and feed it into the furnace. There would be an advantage in using compressed air jets, in order to conserve high-pressure steam.

Other Power-House Auxiliaries. Coal-handling and ash-handling equipment, service pumps, and drainage pumps are usually operated by the cheapest form of motor and power available in the station, which is frequently the slip-ring motor running on power furnished by the house transformers.

Effect of Availability of Main Unit on Auxiliaries

The greater the percentage of time that the power stations are available for service, the smaller the amount of spare capacity that will be necessary and, therefore, the smaller capital charges per kilowatt-hour. In addition, the availability of the most efficient unit has a marked effect on coal costs of not only the power house but also the system to which it supplies power. Interest charges are approximately $2000 per day for each of the two initial 40,000-kw. units installed in a station, and about two-thirds of this amount for any additional units installed. The large amount of this interest charge has caused the installation of duplicate auxiliaries in practically all modern plants and in most modern plants the equivalent of twin condensers and the expenditure of money to duplicate other pieces of equipment, the shutting down of which would prevent the operation of a large unit. Operating with only one half of a twin condenser will reduce the vacuum on the main unit from $^1/_4$ to $^1/_2$ in. The loss for each day that a boiler is out of service is approximately one-sixth of that of the entire plant. This is probably one of the main arguments leading to the installation of powdered coal as the auxiliaries are outside the boiler, and if duplicate auxiliaries are provided they can be repaired without the boiler having to be taken out of service. The use of water-cooled furnace walls should also materially affect the availability. These improvements should increase the availability of the boiler till it compares favorably with that of the steam turbine.

An examination of the boiler capacity in twenty-one new plants, data on which have been available inside of the last fifteen months, shows that in thirteen of the plants induced-draft fans were installed. Forty-six per cent of the boiler horsepower equipped with induced-draft fans had double motors driving these fans. In the other plants equipped with induced-draft fans the average height of the stack was 191 ft., which permits of fair ratings being maintained from the boiler even in case of failure of the induced-draft fan.

The use of two motors per fan enables normal loads to be carried very efficiently; and in addition to providing a second motor in case of the burning out of the motor ordinarily used, it provides a larger motor which can be used when excess capacity is required. The reduction in power losses helps to pay for the additional investment, which is a very small percentage of the investment in boiler capacity. In a few cases duplicate fans are installed. This may be necessary if light fans are selected; but if heavy slow-speed plate-type fans are used, they will be found to be very reliable.

In most power plants equipped with stokers, either there is a common duct into which all forced-draft fans discharge, or, in case individual fans are provided per boiler, the ducts are interconnected so that in case of failure of any fan the dampers between that boiler and the neighboring ones can be opened and the boiler operated while the fan or drive is undergoing repairs.

The stoker and clinker-grinder motors are small, are usually underloaded, and are very seldom installed in duplicate. Spare motors are usually carried, and can be quickly put in place if needed.

Variable Speed

Variable capacity of power-house auxiliaries is accomplished in one of two ways: either by controlling the speed at which the auxiliary operates, or by letting it run at a constant speed and throttling the discharge.

Circulating Pumps. A slight variation in circulating-pump speed is all that is required to control the amount of water discharged by it. Very few working points are necessary, as it is very difficult to determine what amount of water passing through the condenser gives the most efficient results.

Two means of controlling the circulating pumps are frequently used, the most common being with a variable-speed motor. In some cases pole-changing motors have been installed which have two speeds, one being approximately 70 per cent of the other. This gives approximately four different quantities of water if duplicate pumps are installed. This latter method is slightly more efficient, but does not give the number of different operating speeds which can be obtained with the other.

Condensate Pumps. Condensate pumps are nominally operated at constant speed. There has been a general practice of installing too large condensate pumps. Some operators claim that there is an advantage in keeping the level in the hotwell constant in order to prevent the entrainment of air in the condensate. If this is advisable with the newer type of condensers, a float can be installed to maintain a constant level in the hotwell, either by regulating the speed or controlling the discharge head of the condensate pump.

Air Pumps. A hydraulic pump must be operated at constant speed to give the best results. The characteristics of the reciprocating type of air pump are such that variable speed does not greatly improve the efficiency. With steam ejectors, the number of ejectors in service is regulated so as to provide the right amount of air-removal capacity.

Boiler-Feed Pumps. The initial motor-driven boiler-feed pumps were either allowed to run constant speed, the swings being taken on steam pumps, or the motor speed was controlled by hand.

Constant-speed motor-driven pumps were installed in the Spring-

dale station and on the discharge of the pump a 6-in. excess-pressure boiler-feed-pump regulator was placed which was to act as a reducing valve and keep the discharge pressure on the pump a constant amount above the steam pressure. The experience with two valves of this type, which were controlled by pistons, was not satisfactory; and as pilot-motor control had been successfully worked out for motors driving the fans and stokers, it was decided to apply the same principle to a balanced throttling valve. This valve was controlled by a small piston similar to those used in the excess-pressure regulators, but instead of controlling the balanced valve it controlled the current to the pilot motor that opened or closed the valve through a large worm reduction gear. This arrangement gave an absolute control of the position of the valve; as the rate of movement was slow, there was no danger of the valve's hunting or hammering. This valve has now been perfected, and all the motor-driven boiler-feed pumps for the four units in Springdale and the last two installed at Windsor are equipped with it.

This same regulator is being used for controlling the steam to the steam-driven pumps; and we have contemplated its use also to operate the rheostat controlling the current supplied to the motor-driven pumps.

The latest boiler-feed pumps installed in Springdale are driven by slip-ring motors, the rheostats in the secondary of which are adjusted by hand in accordance with major variations in the load of the unit with which it is operated. The variations below that capacity are taken by the throttling regulator. In case the regulator closes or opens wide, an alarm is sounded which notifies the operator. As the load is very steady, the loss in efficiency is probably very little more than when controlling by the rheostat. There is probably a reduction in wear and tear on the pump if the discharge pressure is controlled by varying the speed of the motor. Apparatus has been developed which would automatically change the position of the controller on the slip-ring motor; but we have not used this as yet, as the operators are satisfied to make the few adjustments required by hand.

Forced- and Induced-Draft Fans. Forced- and induced-draft fans require a speed variation of approximately two to one for normal operation, with provision for such overload rating as may be considered necessary. This variation is not readily attainable with a single slip-ring motor unless it is of the pole-changing type. Except for the control of furnace pressure, close regulation is not essential.

The Springdale plant was one of the first in which electrically driven alternating-current motors were designed for automatic operation.

As explained more fully in the Heat-Balance Section of last year's Prime Movers Report, and in articles by motor manufacturers, the induced-draft fan was equipped with two motors, the smaller being sufficient to carry up to normal loads, and the larger up to 33 per cent overload. This arrangement has small power losses at normal loads, and the power losses compare favorably with those of more expensive motors.

In the case of the forced-draft fan, a brush-shifting motor was installed; and in order to insure reliability of service should there be a burnout of the motor or trouble with fan bearings, the forced-draft ducts of the various units were interconnected.

It was thought that this brush-shifting motor, which had an infinite number of operating positions, would give satisfactory results when controlling the furnace pressure automatically; but experience with it has indicated that variations in furnace pressure were too quick to be successfully controlled by it, and a combination of damper control along with shifting of the brushes has been required for satisfactory service. This combination of damper control with automatic shifting of the brushes increased the power loss on an average about 3 kw. per hr., which is a very slight increase on a boiler the normal capacity of which is 10,000 kw. per hr., or $^{3}/_{100}$ of 1 per cent.

Sudden changes in steam pressure are not desirable. Automatic control of the induced-draft fans by varying the resistance of the secondary gave satisfactory steam-pressure control, normal variations being approximately 5 lb. on a header having a normal pressure of 320 lb. The rate of producing steam varied only slightly at any time, which is a condition that should give maximum efficiency in boiler operation.

The amount of money invested in these special motors and complicated fan controls was large. Tests which have been run to obtain the power consumption of motors operating on damper control only have led to the opinion that with the coal conditions under which the plant is operating, there is not sufficient saving to justify a large expenditure for expensive control or motors, and that it would pay to put in a slip-ring motor and use a combination of automatic and hand control.

Tests run on the smaller induced-draft fan motor on one of the older boilers in Springdale indicate that when producing approximately 160,000 lb. of steam per hour the power input is the same irrespective of whether the variation in steam output is controlled by a rheostat or by a damper. The average power requirements when operating between outputs of 85,000 to 165,000 lb. per hr. is 98 kw. when using a damper and 81 kw. when controlling by a rheostat, or a difference of 17 kw. Assuming that this boiler is operated 6600 hours per year, this means a loss during the year of 112,200 kw-hr. The value of this increased loss is approximately the incremental cost of coal. In a modern station operated with coal at \$2.50 the loss would amount to \$168 per year; with \$5.00 coal it would be \$336 and with \$7.50 coal, \$504. With cheap coal this saving on account of the reduction in losses just about pays for the additional expense; while with expensive coal it would justify any additional installation of duplicate motors or other more expensive types of motors which have higher average efficiencies.

Stoker and Clinker-Grinder Motors. The most common type of drive for stokers and clinker grinders is the direct-current motor. These motors are usually comparatively small in size, and it does not require a large motor-generator set to take care of the entire requirements of the station.

Alternating-current motors of the pole-changing type with resistance control can be designed to give satisfactory changes in speed, and pole-changing alternating-current motors with mechanical devices are also used satisfactorily.

Types of Motors

The motor manufacturers have brought out numerous motors suitable for driving auxiliaries of various types. One of the earlier troubles was from the starting equipment of motors. The power on the auxiliary bus of the modern large power house was more than standard starting equipment would break successfully in case of trouble.

The first step in securing better starting equipment was the introduction of half-voltage starting, which was later followed by motors designed for full-voltage starting. This has involved reinforcing the coils only.

Full-voltage starting has the advantage that in case of failure of power and reëstablishment of it the auxiliaries will automatically be restarted. This would be a big advantage in a boiler room where, when the load is thrown off the turbine, it is desirable to reduce the steaming capacity of the boilers as quickly as possible to prevent the loss of distilled water. When load is knocked off the system it is usually some time after service is reëstablished before service is again demanded; in fact, it is very seldom after such an occurrence that the full load is ever demanded that same day.

Starting current which amounts to six or seven times normal may or may not be objectionable. When it is objectionable, double-wound squirrel-cage motors can be used. However, if a variable-speed motor is required, the starting current at the most will not be in excess of two-thirds of what it is for the slip-ring motor.

Selection of the Type of Motor

The selection of the type of motor will depend on the value of power. Practically any type of motor when operating near full capacity has high efficiency. In fact, a squirrel-cage motor has a higher efficiency than a brush-shifting motor at full load. If, then, we charge the simpler type of motor with only the incremental cost of power, for the power losses at part load, we shall considerably reduce the amount of money which we can expend for motors which will give higher average efficiency. If it is necessary to use dampers in order to get fine control with either motors or turbine-driven auxiliaries, the net saving will be even less.

The incremental cost of power in the case of a motor that is in-

efficient at part load would be the average cost of a slight increase in output, the majority of the increase occurring at the lightest loads on the plant. Under such conditions the unit cost would be considerably below the average cost and would probably equal the unit cost of coal.

Discussion

G. C. DANIELS[1] said that the author was particularly well fitted to present a paper on station auxiliaries, because he had been chairman of the sub-committee on that subject in the Prime Movers Committee for the last few years and had gathered voluminous data.

Among the points brought out in the paper was the combination of a house generator on the end of the shaft of the main generator. Mr. Daniels thought the East Peoria plant of the Illinois Electric Power Company had been the first company to purchase this combination—in January, 1923. Since then quite a number of such combinations had been purchased. It had been found that it did not increase the length of space required because it required just that space to withdraw the rotor. It did not matter whether the house generator was at the end of the shaft or not. In order to apply excitation to the main unit instead of having the exciter on the end of the shaft a separate motor-driven exciter was provided for supplying the excitation to the main unit. This was driven off the house generator electrically. The house generator had its exciter mounted on the end of the shaft. It had been found very early that the two house generators could not be tied together because they would divide the load according to the load on the main generators. Each house generator supplied the important auxiliaries for its unit of turbines and boilers, which included the circulating pumps, exciters, pulverized-coal feeders, blast fans, and induced-blast fans, and all other auxiliary power was taken off the main bus. The house generators were interconnected so one could carry the load of the other, or one could be taken off the main bus. The main objection that Mr. Daniels' firm had to steam auxiliaries was not so much a question of efficiency—if only used as a stand-by outfit the power required was very slight—as one of complication of station piping. Not only was there a great deal of high-pressure piping in the modern plant, but there was trouble in draining these pipes when not in service, giving rise to complications and the necessity of traps and drains. Their high-pressure piping was drained at the throttle valve through the steam-jet air ejector, so that, in starting up, the air ejector was first turned on and the pipe leading to the turbine was drained. They only had one steam-driven boiler-feed pump, which would be trapped, the only high-pressure trap they had. The other boiler-feed pumps were motor driven, and in order to get regulation a Klingman-Ruggles regulator was used which regulated all the motors that were in service. It had been found that a 15 per cent speed reduction was ample for all requirements of pressure. By having all of the pumps regulated from a common source, they were all operating at the predetermined speed made necessary by the pressure required, and as another pump was required a push-button control put it on. The pump was brought up to 85 per cent speed on the starting device and was then put into running position. The pressure curve was such that the pump would immediately divide its load with the other pumps in operation, so it was assured that each pump would take its proportion of the total water pumped.

Uniflow and Compound Duoflow Engines

A Review of the Development and History of These Two Types of Reciprocating Engines and a Discussion of Their Respective Fields of Application

By ROBERT CRAMER,[2] MILWAUKEE, WIS.

STEAM-ENGINE designers in our day judge the excellence of a design mainly from the standpoint of thermodynamics. This science may be said to have been developed more to test the creations of practical engineering, than to make practical engineering follow the scientific deductions of thermodynamics. It is clearly recognized today by all practical designers, in spite of their reluctance to rely on theory, that to make steam engines efficient all heat must be absorbed by the steam at as high a temperature as possible and rejected at as low a temperature as possible. This is a logical deduction from the second law of thermodynamics. Under this simple law come also the adoption of higher steam pressure, low condenser pressure, and the use of superheat. But on account of cylinder condensation, due to the large temperature difference existing in a single cylinder in the case of a large ratio of expansion, it was recognized early in a practical way that there are certain limitations to the realization of theoretical requirements.

A solution of this problem was found in what is known as compounding, the expansion being carried out in two or more cylinders, reducing the loss due to cylinder condensation in each in proportion to the corresponding reduction of the temperature difference. Another solution is presented by the uniflow engine.

Operation of the Uniflow Engine

After expansion has taken place steam is exhausted in this case through a port which the piston overtravels at the end of the expansion stroke. It is evident that the piston must again cross the port when it has moved but a short distance on its return stroke. The clearance is proportioned in such a way that the pressure at the end of the return stroke is equal, or nearly equal, to the admission pressure. The result of this is that the incoming new steam meets steam of approximately the same temperature as its own; and therefore no part of the incoming steam is condensed.

There is another feature of this arrangement which is important. In the compound type of steam engine steam is admitted and discharged through the same port or through two ports, both of which are located at the same end. The exhaust steam is swept through the length of the cylinder, and as it is cool and the cylinder is warm, it has a chilling effect upon the cylinder walls.

In the uniflow engine the steam remains practically stationary in the cylinder and there is no such action and no chilling. It seems that the uniflow engine can do in one cylinder what other engines do in two or more.

Limitations of the Uniflow Principle

However, there are other influences which make complete realization of the ideal impossible. In the first place, should expansion be carried to the level of the back pressure, then the compression curve would retrace the expansion curve and the engine would not do any work at all. This means that in practical uniflow-engine design a compromise must be reached, in such a way that the gain resulting from uniflow action is more than sufficient to offset the loss due to incomplete expansion. In reaching this compromise it must also be borne in mind that the greater the ratio of expansion, the larger and more costly the engine will be for a given rating.

Another important source of loss in the uniflow engine, especially when working non-condensing, is in its large clearance. The latter has always been known as a source of loss of steam-engine economy, and in this discussion we may make use of this well-known fact without going into its cause.

It is easily seen that an engine compressing steam for nearly the full length of the stroke, when this compression begins with

[1] Supvg. Engr., Hodenpyl, Hardy & Co., 316 S. Jefferson St., Peoria, Ill. Mem. A.S.M.E.

[2] Consulting Engineer. Mem. A.S.M.E.

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atmospheric pressure, must have a very large clearance. Uniflow engines are designed with special pockets in the heads to provide this large clearance, or are made with hollowed-out piston heads.

It is for these reasons that the modern uniflow engine is a compromise in more ways than one. Several methods to meet the conflicting requirements of this engine type have been proposed, but the one which seems to be the most promising, and which probably will be adopted universally in the future, is that of shortening the compression. Many engines built today are provided with auxiliary exhaust valves which are kept open when the exhaust stroke begins and are closed at any desired point. This arrangement makes it possible to reduce the clearance in non-condensing engines and still reach the admission pressure at the end of the compression. On the other hand, this arrangement reintroduces to a certain degree the sweeping action of the exhaust steam, with a corresponding chilling effect. Nevertheless, it has been found that a good practical and economical compromise can be worked out, and many engines of this type are now in operation.

Relative Economy of Uniflow and Compound Engines

While the uniflow engine has displaced a good many engines of older types, it has not been able to take completely the field formerly occupied by compound and multiple-expansion engines. It has found a field in which it is now predominant, but it has left other fields to other engines. It is, of course, important to note in this respect that in larger units the steam turbine has taken the place of all types of steam engines. Reciprocating steam engines are no longer used for the main unit in large power stations.

In the remaining field the uniflow engine and other types are used in accordance with their peculiar characteristics, and it is well to note what these characteristics are.

It has often been stated that for any given condition of steam pressure, superheat, and exhaust pressure, compound engines, and even more so multiple-expansion engines, can be designed to give a better economy than any uniflow engine for the same conditions. This is true, but compound and multiple-expansion engines if so designed, while more economical for the load for which they were designed, will not be so for loads above and below this best load. In other words, the uniflow engine has a characteristic *flat economy curve*, whereas the economy curves of compound and multiple-expansion engines rise whenever the load goes above or below the best.

Also, if a given engine is used under varying load conditions, the average economy of the uniflow engine will usually be better than the average economy of compound and multiple-expansion engines, although the best performance of the latter is better than the best of the uniflow.

Fields of Application of the Uniflow and Compound Engines

These different characteristics of these engines have brought about the prominence of each in its particular field. The uniflow engine today is used to the greatest extent in small industrial installations, and especially in factory drives where power and heat requirements are combined. Variable loads are common in installations of this kind, and the fact that exhaust steam can be used for heating either during the whole or a part of the year makes the use of a steam engine more economical than the buying of power, even at low rates.

On the other hand, whenever loads are steady, the uniflow engine has not successfully replaced compound and multiple-expansion engines. A typical example of this kind is found in marine installations, especially in smaller freight boats, where loads are uniform excepting for the very small percentage of time used in maneuvering. The advantages which the uniflow engine possesses for marine work on account of the fact that all the cylinders in multiple-cylinder engines are alike, have not been able to secure for it this field, where fuel economy is of prime importance.

In both of these fields, factory drives and marine work, the use of the steam engine is being seriously contested by other types of engines or other methods of securing power. In the marine field, in which the multiple-expansion engine has held sway for so long a time, the steam turbine is now universally used for units of large power. In the medium-sized and smaller units oil engines are often preferred to steam engines, and possibly will be used universally in the not-too-distant future. In industrial applications steam turbines are used for larger power requirements, and in such cases they are more economical than in the isolated plant.

It is interesting to note that in the field of small marine installations the compound steam engine still remains almost undisputed, and that in the industrial field the uniflow engine has gained a secure position in the smaller sizes where steam-turbine economy is poor and wherever central-station power, on account of the use of exhaust steam, is not economical.

One late and interesting development in this last-mentioned field is the multiple-cylinder vertical uniflow engine, which is finding favor on account of the remarkably small floor space it requires.

Discussion

Herbert S. Philbrick,[1] the chairman, asked the author to restate briefly what field the uniflow engine had found entirely for itself.

The author, Mr. Cramer, stated that the reason for the eminence of the uniflow engine in the industrial field was simply the fact that it had good economy under great variation of load, both condensing and non-condensing, if built for those varying conditions. One of the outstanding features was that this engine, the economy of which was not important when exhaust steam could be used for heating, showed a good economy when the exhaust had to be wasted, as was the case in summer. Another important feature was that the engine was cheaper to build than a compound engine in every way, and that had been brought about through various compromises.

In the case of great power requirements, said Mr. Cramer, steam turbines would meet the conditions better than any reciprocating engine from the standpoints of cost, space, and other considerations, but it was in the restricted field of medium-sized and smaller industrial plants, where it paid to produce power (because exhaust steam could be used, at least during part of the year), that the uniflow engine had found its best market and where it was used almost exclusively today.

B. E. Seamon inquired about the adaptation of the uniflow engine to the refrigeration field. The author answered that uniflow-engine builders had furnished quite a number of engines of this type for driving ammonia compressors.

W. L. Abbott[2] stated that some years ago the Prime Movers' Committee of the N.E.L.A. had looked into the subject of uniflow engines and, as he understood it, had found that the uniflow engine could not compete with the compound engine over quite a range of load. It was possible that at higher or lower loads it could compete, but in the ordinary working range, particularly such as one used in the fairly steady work of electric-light production, he thought that the compound engine would be more economical.

Mr. Cramer admitted that for a given load a compound engine which had been worked out with all the refinements known to the art could, for given conditions, be made superior in steam economy to the uniflow engine. That engine, however, in most cases would cost more than the corresponding uniflow engine. The initial cost, in the case of a central station, was not as important an item as it was in most industrial applications. It was a fact that in this country the uniflow engine had never found its place in central stations, except in a few isolated cases of small stations. That was not so, however, in foreign countries. Before the steam turbine had been developed to the point where we know it today, even twenty years ago, the uniflow engine had been used to a very large extent in the power plants of Germany and France, and somewhat in England, Belgium, and Austria. The reason for its use had always been superior overall economy, taking the cost of installation into account, as compared with compound or triple-expansion engines.

For the principal prime mover in a central station the field today was held by the steam turbine, and would be held by the steam

[1] Professor of Mechanical Engineering, Northwestern University, Evanston, Ill. Mem. A.S.M.E.

[2] Chief Operating Engineer, Commonwealth Edison Co., Chicago, Ill. Mem. A.S.M.E.

turbine until something better came forward, but the uniflow engine was eminently suited for the industrial field with the limitations mentioned.

Mr. Abbott asked if the uniflow engine at high initial and high exhaust pressures was more economical than the steam turbine within that range.

Mr. Cramer found this to be too general a question. In his experience in power-plant engineering he had known of many cases where the smallest and crudest steam engine was far superior to any steam turbine that could be built from 5 to 200 hp. In that case the uniflow engine could certainly far outstrip any other engine. On the other hand, with engines such as were used in small stations today, there was no uniflow that could possibly approach steam turbines in economy.

Combustion Control

Difficulty of Controlling Air-Fuel Ratio—Advantages of Combustion Control—Control of Steam and Air Pressures—Feedwater Control—Savings Effected

By T. A. PEEBLES,[1] PITTSBURGH, PA.

A NEGATIVE definition is sometimes of value because it is easier to state in a few words what a thing is *not* than to give a comprehensive definition of what it is.

A negative definition of combustion control is, "Combustion control is not a substitute for a capable stoker operator." It is not possible by the installation of a system of combustion control to reduce the stoker operator to the level of a laborer whose duty it is to see that the stokers are kept properly lubricated and the hoppers filled with coal. The reason why this cannot be done is because of the variable factors with which a system of combustion control has to deal, and not because the apparatus itself is crude and unreliable.

The limitations can readily be appreciated after a little study of the conditions under which a system of combustion control must operate. Broadly speaking, there are two results to be secured:

1 The proper proportioning of fuel and air
2 Variation of the fuel and air quantities in proportion to the load requirements.

Difficulty of Controlling the Air-Fuel Ratio

The air for combustion is supplied by means of a fan or chimney and the quantity is controlled by adjusting one or more dampers or controlling the speed of the draft fan. It is easy to control either of these elements, but difficult to control them in such a manner that the quantity of air being supplied will bear the correct relation to the quantity of fuel supplied. In the case of chimney draft regulated by a boiler damper, the weight of air drawn in will vary for a given position of the boiler damper with changing atmospheric and temperature conditions and with any condition existing within the boiler setting itself, which may affect the draft loss or the temperature at which the gases leave the boiler.

When it comes to considering the supply of coal, many factors are introduced to complicate the problem. It is not a difficult matter to establish a relation between stoker speed and quantity of air being supplied, but this will not insure the proper air-fuel ratio. If the stoker hoppers are kept properly filled and there is nothing to interfere with the free flow of coal to the feeding mechanism of the stoker, the volume of coal fed will bear a fairly close relation to the stoker speed. However, the percentage of fines in a coal will affect the weight per cubic foot; and even if the stoker puts in the correct number of cubic feet, it will not necessarily put in the correct weight. Furthermore, coal which is free from surface moisture will not give the same results as coal containing surface moisture. Ordinary screenings will weigh from 5 to 10 per cent less per cubic foot when containing 5 per cent surface moisture than when free from surface moisture. There will therefore be a difference of 10 per cent or more in the actual weight of fuel delivered for a given stoker speed, even assuming that the coal is all of the same general quality and has the same B.t.u. per pound, dry. Under conditions of varying size and surface moisture of the coal, a definite relation between stoker speed and weight of air supplied for combustion will not necessarily maintain the correct air-fuel ratio. Something very much more elaborate than control of stoker speed in accordance with air supply is necessary if the equipment is going to be entirely automatic and the stoker operator is to be practically eliminated.

A change in the quality of the coal will produce a change in the fuel-bed condition which will not become apparent immediately, but which, if allowed to continue, will eventually produce unfavorable conditions. The quantity of fuel in a furnace at any given time permits of short periods when the coal supply is not in proper relation to the air supply without producing any unfavorable condition, but in case these periods should be of long duration, it requires the attention of a capable operator to make such adjustments as may be necessary to adjust the stoker speed to reëstablish the correct condition.

A correction might be applied in accordance with variations in the CO_2 content of the gases leaving the boiler, or by the relation of air flow to steam flow. Neither of these arrangements is entirely satisfactory because the quantity of coal in the furnace does not necessarily determine whether or not proper contact is being secured between the fuel and the air supplied for combustion. For instance, the CO_2 might be low, not due to the fact that there is insufficient fuel in the furnace, but because the fuel bed is irregular, or because there are clinker accumulations along the side walls or on the grate surface itself. The remedy in such cases is, of course, not to supply additional fuel to the furnace, but to remove the clinker formations.

In the combustion of oil, gas, or powdered coal many of the variable conditions which must be corrected for by the operator are either absent or present to a smaller degree than in the case of stoker firing, and the combustion control can more closely approach the ideal of complete automatic operation. It is a fact, however, that the mechanical stoker will continue to be used in a large majority of coal-burning plants, and it is in this field of application that the greatest benefits are to to be expected from the intelligent use of combustion-control equipment.

Advantages of Combustion Control

In spite of the limitations which prevent control equipment from replacing the stoker operator, it can be of great assistance to him, and if the relation of one to the other is thoroughly appreciated and the work divided as it should be, a substantial improvement in overall results is to be expected.

Control of Steam Pressure

It is desirable that the steam pressure be maintained uniform within a few pounds, and the adjustments necessary to accomplish this end are made much more satisfactorily by automatic means than by hand. Where the load is at all irregular, a larger part of the fireman's time is consumed watching the pressure gage and in adjusting the air supply. A master regulator, operating in accordance with changes in the header pressure, can be utilized to vary the air supply and the coal supply simultaneously, or it can vary the air supply alone, a second automatic unit adjusting the stoker speed in accordance with the change in air supply. If these adjustments are made in proportion to the change in header

[1] Ch. Engr. The Hagan Corp., 1301 Chamber of Commerce Bldg. Mem. A.S.M.E.

Presented at the Second Annual Power Meeting, Jan. 14 and 15, 1925, of the Chicago Section of The American Society of Mechanical Engineers.

pressure, the steam pressure is automatically maintained within the desired limits, provided, of course, that the equipment in service is not overloaded and that the fuel beds are kept in proper condition. The simultaneous regulation of fuel and air, or the regulation of one with relation to the other, would, under ideal conditions, maintain a uniform fuel-bed condition, but the variable factors encountered in stoker operation will require a certain amount of attention on the part of the operator. Since he has been relieved of all work except that of keeping the fuel beds in proper condition, he has ample opportunity to observe any departure from desirable conditions, and to make the necessary corrections. One of the principal reasons why improved overall results can be secured by this division of work between the operator and the automatic-control equipment is that the operator is free to devote his undivided attention to the fuel beds, and can therefore keep them in better condition than would be possible if he were required to make all other adjustments.

Control of Air Pressure

Fuel-bed resistances vary over wide limits due to the changes in the fineness and moisture content of the coal, and it is a proper function of automatic-control equipment to compensate for these variations, insuring that a porous fire does not get more air than a more dense one. In the case of forced-draft stoker installations, it is also a proper function of the control equipment to maintain the desired draft in the combustion chamber. The importance of maintaining this constant draft has probably been overestimated in the past. If it were as important as we might be led to believe from some statements, that the combustion chamber pressure be almost equal to the atmospheric pressure, it is difficult to see how a natural-draft stoker could give the excellent results which have been recorded in numerous instances. There is a gain in keeping the furnace draft as low as possible, as this reduces the suction throughout the entire boiler setting and reduces the air infiltration, preventing also excessive maintenance which results from a positive furnace pressure, but a constant furnace draft alone does not insure efficient combustion.

A properly working system of combustion control reacts favorably on many conditions apart from the actual maintenance of the air-fuel ratio and the variations in the quantity of fuel and air in accordance with load conditions.

Feedwater Control

Adjustments of air supply have a definite effect on the operation of feedwater controllers. The time required for a particle of air to travel from the wind box under the stoker, through the fuel bed and combustion chamber, over the heating surface, and out through the boiler damper, is from two to four seconds, depending upon the dimensions of the boiler and the rating at which it is being operated. It follows, therefore, that the rate at which the boiler absorbs heat is affected almost instantaneously by an adjustment of air supply. The rate of heat absorption affects the circulation of water in the boiler and consequently has an effect upon the water level. A sudden increase in the rate of air supply will cause a rise in water level, which in turn affects the rate at which the feedwater controller allows water to enter the boiler. Where the plant load is irregular and frequent adjustments of air supply are required, the operator must make these adjustments with considerable care or a fluctuating water-level condition will be produced which renders it practically impossible for feedwater controllers to operate as they should. When these adjustments are made automatically they are made simultaneously on all boilers, and the adjustment begins as soon as the pressure conditions in the header indicate the necessity for such adjustments. The adjustments are therefore made gradually, giving the feedwater regulator time to function properly, with the result that satisfactory feedwater regulation is secured even under extreme conditions of load fluctuation.

Superheat

There is a natural tendency for the superheat to change with the rating at which the boiler is operated. Since the fuel and air adjustment can be made more gradually and at the proper time by automatic means, it follows that the boilers can be kept operating more closely to the actual load requirements than can be done by any except the most careful and skilled hand operation, with the result that the superheat is maintained more nearly uniform.

Tube Replacements

Improper regulation of the air for combustion will have a serious effect on boiler tubes, especially where unfavorable water conditions exist. At periods of high rating the rapid circulation tends to stir up the suspended impurities and distribute them throughout the entire boiler. If the draft is then checked to considerable amount, the circulation is greatly reduced, and the impurities settle on all horizontal or inclined tube surfaces where they will tend to adhere to the hot metal surfaces. This condition, repeated many times, will eventually result in the overheating and burning of those tubes exposed to the highest temperature.

Clinker Formation

The formation of clinker is most pronounced when boilers are operated at higher ratings and when furnace temperatures are high. If there are periods of operation with hand adjustment of the draft when the rating is lower than it should be, there must follow periods when the rating is unnecessarily high, and the tendency to produce clinkers, therefore, is aggravated.

Maintenance Cost

The more uniform it is possible to maintain the fuel and air supply, the more nearly uniform will be the furnace temperature and the better will be the conditions for long life of the furnace linings and metal parts of the stoker. This is particularly true of firebrick arches of all kinds.

Efficiency

The effect of automatic control on overall efficiency is, of course, the question that is of greatest importance to engineers. No general statements can be made because the margin between the best possible results under existing conditions and those actually being secured will vary over wide limits. In large, well-operated plants there is of course a very much smaller margin than in the smaller plants, which do not have the advantage of skilled supervision such as is available in all large stations. In the best-operated stations the margin is small, probably not more than 3 or 4 per cent. A part of this can be recovered by the use of control equipment, primarily for the reason that the operator is enabled to devote his entire time to watching the fuel beds and maintaining them in the condition he knows to be best.

In the smaller central stations and large industrial plants the margin is usually from 5 to 10 or 12 per cent. At least half of this can be saved in most cases, because in such plants the operator is neither as highly skilled nor as well directed as in the larger plants, and control equipment effects a saving by proper adjustment of the fuel and air supply to meet the load conditions in addition to permitting the fireman to give better attention to the condition of the fire.

It is hard to believe some of the savings that have been effected in the small plants. The margin between actual results and those possible with the existing equipment is anywhere from 10 to 40 per cent. In extreme cases the proper application of combustion-control equipment has reduced the fuel consumption as much as 30 per cent, and from 10 to 15 per cent is quite common. The general improvement in operating conditions as to uniformity of steam pressure, reduced production of smoke, better feedwater and superheat control, and reduced maintenance cost, are also most pronounced in these plants.

Discussion

A. E. GRUNERT[1] who opened the discussion, said that he believed with the author that the automatic regulator would not necessarily eliminate a good fireman, because there were so many variables in firing coal. In large stations the control would regulate a number of boilers working on a common header, and it was improbable that fuel conditions in each one of the stokers would be identical. In one stoker the coal might be a little dry, in another

[1] Efficiency Engr. Commonwealth Edison Co., Fiske and 22nd St., Chicago, Ill. Mem. A.S.M.E.

the sizing would be coarse, in another one some other condition would be different. A regulator controlled by steam pressure would affect all stokers rather than the condition causing the drop in pressure. It seemed to him that if it was going to be 100 per cent successful, regulation should be developed to such a degree that it would eliminate the trouble at the source.

The author did not favor particularly an atmospheric pressure over the fire in forced-draft operation. In Mr. Grunert's experience he had found that what was ordinarily referred to as a balanced draft was impossible from the standpoint of brickwork maintenance, and a regulator that would prevent a balanced condition would be beneficial, on account of the saving of the brickwork. Regulating the over-fire draft where the control was placed on the forced-blast fan did remove one operation from the fireman. In a forced-blast stoker a fireman, to regulate manually, had to think of three things: the condition of his fuel bed, the induced-draft fan, and the forced-blast fans. Obviously, if he desired to change the rating on a boiler, the thing to do would be to reduce the speed of both fans and the amount of grate feed. Mr. Grunert had never yet seen a fireman that could do this right the first time. He had either reduced the draft fan too much or not enough, or if that was all right, the forced-draft fans had been reduced too much or not enough. If the control of the forced-blast fan was effected by an automatic regulator, one of the three of the fireman's operations was eliminated.

Joseph Harrington,[1] said that the author had presented a well-balanced and impartial analysis, but he felt that the question really should be again subdivided on the basis of the large and the small station. While technically the laws of combustion were identically the same, it was a fact that practically they were different in their application.

As the author had brought out, the large number of units of a large station had a sort of flywheel effect, so that the variation in any one was not apparent at the other end of the steam line. Also it was customary in larger plants to control groups of boilers on a single header, which introduced another complication and made automatic control a little more difficult.

Referring, however, to the great number of small plants burning the major portion of the soft coal, Mr. Harrington agreed thoroughly with the author that the condition in the average plant—using word "average" advisedly, taking in every plant from two or three thousand horsepower down—the conditions were indescribably poor. There was no doubt in his mind but that a well-planned and well-applied system of combustion control was one of the greatest factors in increasing the economy of such a plant.

A few years ago he had had occasion to put a flowmeter on a feedwater line in order to show the firemen how to regulate feedwater. This 500-hp. Stirling boiler had a 2-in. feed line, hand controlled, the fireman operating the valve as he deemed necessary. The flowmeter had shown that a fraction of a turn of the feed valve would send the recording pen off the chart. It was unnecessary to enlarge upon the evils of that particluar method of operation. Everything was wrong.

Another phase of combustion control which appealed to Mr. Harrington more strongly than anything else was the maintenance of a uniform temperature. In the Middle West there were bituminous coals which were somewhat given to clinkering if not treated properly. As a rule the temperature within the fuel bed, and indeed within the furnace, was generally higher than the melting point of the ash. The ash was kept from fusing on the grate surface of a stoker only by the air which passed through it. If this flow of air was suddenly discontinued, the temperature of the ash immediately above the stoker would rise quickly and the ash would fuse into a clinker. There was no one thing that worried the stoker operator as much as clinkers, and anything which would reduce this evil was a blessing to the power-plant operator.

There were many operations around the plant like these he had mentioned which the operator simply could not perform. He could not judge just how much the damper or the feed valve should be opened to balance the varying requirements of the boiler. It was human nature, which never failed to assert itself in such a contingency, that the man would overdo it. It took indeed a man under very severe self-control not to go to extremes when he saw the water line going down or the steam pressure going down, and as a result, if one would watch recording meters on almost anything about the boiler that was completely hand operated, he would find that conditions varied from one extreme to the other. The production of CO_2 was a continuous chemical process, and if the various ingredients were not supplied in steady proportions, the result would not be right. The author and others who had specialized in this line were engaged in something which Mr. Harrington believed was of absolutely vital necessity to the economical production of steam from bituminous coals.

[1] Consulting Combustion Engr., Riverside, Ill. Mem. A.S.M.E.

C. H. Smoot[1] said that coal cost money, while air was to be had for nothing. After a plant was built the rest did not amount to very much; the coal was the chief expense. It would therefore seem only reasonable to safeguard the coal supply as carefully as possible. The process that took place in the fire was a chemical one. Its efficiency, complete or incomplete combustion, was a question of mixture, supplemented by questions of temperature, fuel bed, etc. It required a quantity control of the air and the fuel. A man was a very poorly constituted mechanism for continuous regulation. A piece of machinery such as a speed governor on an engine or turbine performed its function vastly better than it could be done by man. Consequently, in the boiler room a distinction should be made between control and the exercise of good judgment. Even in a hand-fired plant, the quantity regulation of the air supply allowed the fireman to do a very much better job of shoveling coal. He was guided by the physical condition of the fuel bed.

Primarily the function of the stoker was to convey coal through a chemical process and discharge the remaining ash. The quantity of coal determined the total amount of heat and steam made, and was a very essential thing to control. The quantity of coal in a cubic foot varied with moisture, fines, etc. Nevertheless, the only control of quantity was in the speed of the stoker mechanism. The same speed would not suffice for a different amount of fuel. Once the correct speed was determined the mechanism must do the rest. If, in addition to accurate speed variation there was a change in the character of the fuel, this was the place for the man to take hold of the problem. Here the man and not the machine must be the compensating element. In a boiler plant there was normally a continued strife between the ability of the organization running the plant and the natural inertia of inanimate objects. It seemed only just to supply a man with all possible tools to allow him to get results. He should be given the instruments to see what he was doing. The performance of the plant should be logged on a chart so he could see, and so the boss could check up and see, how reasonably the plant had been conducted. One phase of the job was keeping books on the operation of the boiler plant.

Aside from this there was a second phase, the actual running of the plant. The operator was confronted with conditions which called for action. He had no chance to stop and think. He had to go ahead and do. He must be provided with mechanical equipment which would do the thinking as far as possible. In addition to this, his native wit and ability in running that plant should be confronted with the least delay, the least worry, and the least complexity. Maybe it would be only a few push buttons, but anything which would give him contact and control of all the fires and boilers would make for improvement in the efficiency of that plant. The fireman had it entirely within his power to get results, good, bad, and indifferent. He had a rough, dirty job, calling for strength, backbone, and determination to go through, but on the other hand, we were asking him, without very elaborate support and apparatus, to do a nicely balanced problem in finance, chemistry, and engineering, not once a week but every minute of his day. The greater part of the money that the plant spent went through his hands. It was a profitable investment or not, according to how skilful the fireman was as a chemist and a bookkeeper.

G. S. Carrick[2] said that the author had made a good presentation of the subject of automatic control. If operators would think along the lines of trying to make an automatic control handle their problem, working with automatic control rather than with the firemen, who were changing from day to day, and if they would

[1] Pres., Smoot Engrg. Corp., 136 Liberty St., New York, N. Y. Mem. A.S.M.E.

[2] Pres., Genl. Mgr., Carrick Engrg. Co., 538 So. Clark St., Chicago, Ill. Mem. A.S.M.E.

coöperate, picking out the proper machines for the proper functions, they would eventually have more efficient plants. He predicted that even the largest central stations would eventually be automatically controlled. It might take weeks, months, years, but eventually they were going to operate automatically, and engineers were going to learn not to instruct the firemen how to handle the fires, but how to handle the controls.

J. M. Spitzglass[1] said that he did not see why the author had to make the statement that the speed of the stoker in no way gaged the amount of coal going into the furnace. Had he sufficient time he could prove that it did, even though the water in the coal might vary.

To illustrate, if water was added to the coal, a cubic foot would have a different weight, but the stoker would pass a cubic foot, and that cubic foot would have exactly the same combustion value as before the water was put in. The fact was that when coal was put up through a stoker, and conveyed without being pressed down and its specific gravity changed, equal volumes really did mean equal weights.

We were progressing in this matter of boilers. The first boiler had been operated with a pressure gage only. Later the draft was considered, and then the CO_2. Still later the temperature of the flue gases had been considered, and only very recently, about ten years ago, had we begun to consider the amount of steam generated by the boiler. Then the problem had been raised as to whether the supply of air followed the supply of steam. Of course it had to be checked up by the combustion results. The author had told how to regulate the supply of coal, which, as Mr. Smoot had demonstrated, was really the thing we were paying for. The author had said that we did not need that because it was hard to measure. He wanted to give him this encouragement, and that was, the revolutions for the stoker for a given condition would always give the exact quantity of combustible coal that would be supplied. The weight might vary according to whether more or less water was used, but the combustible weight would be the same, if one measured the stoker feed for a given condition.

The author had not said whether the method of control was the old pressure method, which would act on all the boilers the same way, or what he might call the new way of controlling the boilers by the velocity or by the steam generated in any particular boiler. If the combustion control was effected by following the steam generation, then we need not worry. We might have a dozen boilers on the line and each boiler could be regulated to give the supply of air and the supply of coal in proportion to the flow of steam. He would like to have the author explain exactly which way he proposed to control combustion, by pressure or by volume.

The author, Mr. Peebles, in closing, said that when a certain load was to be handled by a given number of boilers, the operator usually had some choice in the number of boilers he would put on the line. He would put on the number of boilers that from his knowledge of the characteristics of those units would give him the best results. If a man had ten boilers available that he could put on the line, and he knew that the average loading he must handle could be most economically carried by eight of those boilers, he did not drop another one off and force the seven that were left. He would put on the number of boilers which, if each one took its share of that load, would give the best overall results. Then the thing to do would be to arrange the control equipment so that the load would be automatically divided among those boilers, and that could be accomplished by control from the steam pressure in the boiler header, i.e., in the plant header. A change in the rate of flow of steam from a boiler would immediately affect the pressure in the header. There was a drop through the dry pipe, the non-return valve, the superheater, and the piping connections to the main header, and when a plant was under a banked condition the pressure in the header and the pressure in the boiler drums were equal. When the plant began to do work the pressure in the header would go down in proportion to the quantity of steam being passed from those boilers, just the same as the pressure drop across the orifice or the differential pressure of a pitot tube would vary the quantity. So he would say the most satisfactory condition was a control scheme designed so that it responded primarily to pressure variations in the steam header, because these were affected both by the static pressure of steam in the boiler drums and by the quantity of steam that was passing from the boilers. Divide the load equally among the boilers and provide for a correction in the flow of air to each boiler, in accordance with its fuel-bed resistance. We knew that if one stoker had a smaller percentage of fines in it than another, the same quantity of air under both fires would give radically different quantities of air through the fires. Automatic control compensated for these differences and should be expected to do it, putting equal quantities of air through the different fuel beds, regardless of the resistance encountered. If the operator, by making some adjustments to the stoker speed, which he still thought necessary, would keep the fires in the right condition, preventing clinker formations from uncovering sections of the grate surface and keeping the rear end of the stokers reasonably free from excessive accumulations of clinkers, he would get uniform conditions in the boilers, uniform combustion, and uniform steam generation.

The stoker operator must be on the job. He must have at his command, in addition to the automatic control of the stoker speed, the ability to make a slight adjustment by hand. He believed that the stoker speed should be just as carefully calibrated to the air supply as it was physically possible to do it, but he did not believe it was possible to get it just exactly right, on account of the varying moisture content and fines of the coal. There should be some convenient and reliable means by which the operator could change by a small amount the speed of a stoker. He did not by any means believe that there should be a speed control that would enable the operator by hand to add 20 to 40 per cent to the speed of a stoker, but he did believe that small increments should be within his command.

[1] Vice-Pres., Republic Flow Meters Co., Chicago, Ill. Mem. A.S.M.E.

Hydroelectric Progress in Canada During 1924

THE Dominion Water Power and Reclamation Service of the Department of the Interior of Canada has prepared a review of hydroelectric and water-power development in Canada in 1924, which shows that the year has been one of pronounced activity for that industry throughout the Dominion. Not only was a substantial increase recorded in the total installation but many large projects were advanced to such a state that a further extensive increase will be effected during the year 1925. More than 300,000 hp. were added during the year bringing the total installation in the Dominion to a figure of 3,569,275 hp., while with the installations nearing completion this figure will be increased by more than 600,000 hp. during 1925.

Practically every province is represented in the year's activities, and the review clearly shows the tendency towards the increase in the size of individual developments and the speed of construction which are the leading features of present day practice.

Among the projects which are briefly recorded are those of the British Columbia Electric Railway Company and the West Kootenay Power and Light Company in British Columbia; the City of Winnipeg in Manitoba; the Ontario Hydro-Electric Power Commission, the Canadian Niagara Power Company and the Backus Brooks Company in Ontario; the St. Maurice Power Company, the Montreal Light, Heat and Power Consolidated; the Northern Canada Power Company, and the Ottawa River Power Company, in Quebec; and the Nova Scotia Power Commission in Nova Scotia.

Copies of this bulletin may be obtained free of charge on application to the Director of Water Power and Reclamation, Ottawa, Canada.

A Correction

IN THE discussion of Safety in the Operation of Pulverized-Fuel Systems on page 116 of the February issue of Mechanical Engineering, Mr. H. G. Barnhurst calls our attention to the fact that he was reported to have said that in twenty-six years' experience with pulverized fuel he had not seen or known of an explosion except once or twice where elevators had been opened in the presence of open torches. This statement is true only in so far as it refers to the plants with which Mr. Barnhurst happened to be connected or with whose design and construction he had something to do.

Water-Cooled Furnaces

A Description of Several Installations of Fin-Wall Furnaces, Pointing Out Their Advantages

By H. D. SAVAGE,[1] NEW YORK, N. Y.

IT HAS been apparent for several years to those interested in the rapid developments being made in power-plant work, that although the Refractories Manufacturers' Association, through the fellowship they have established at the Mellon Institute as well as the Bureau of Mines, have been doing excellent work in the investigation and development of special refractories, furnace materials and refractories have not been keeping pace with the strides being made in other features of this development. The higher settings, higher ratings, and higher efficiencies now being made have placed a duty upon boiler furnaces that cannot be met satisfactorily by the refractories available or of common and standard use, for while it may be possible to develop in the laboratory high-heat-resisting materials, these same materials, when put into service, may, due to stress of operation or ever-present fluxes in ash, fail entirely to meet the requirements without some artificial aid. This led in the beginning to the development of ventilated blocks, of which there are a number of different types on the market.

The more recent and complete development, however, covers:

1 Hollow-wall refractory furnaces
2 Steam-cooled walls
3 Water-cooled walls.

While the hollow-wall furnace was a tremendous step forward, its application is more practical with powdered fuel than with stokers, so that it meets immediately with limitations. Steam-cooled walls may of course be applied to any type of firing, but naturally the amount of cooling obtained from this source must be limited, as the area possible to expose in the furnace is governed by the amount of superheat required, and up to the present time results obtained would indicate this method of cooling to be not yet out of the experimental stage.

The completely water-cooled furnace or a combination of water-cooled and refractory furnace would seem to present the greatest possibilities for future interest.

This paper will deal with one type of water-cooled furnace, namely, the finned type, or as it is now called, the fin furnace. This furnace has been applied to both stoker and pulverized-fuel installations, and while accurate data covering the net effect of such walls on capacity and economy are too meager for the drawing of conclusions, it is quite possible to discuss it from a practical operating standpoint, since three water-cooled furnaces over stoker fires have been in operation at the Hell Gate plant of The United Electric Light & Power Company for something over a year, and six similar furnaces in connection with pulverized-fuel firing have been in operation at the Sherman Creek plant of the same company for several months. These nine units have been in regular service since their installation and since no unusual operating difficulties have developed, it may be proper to assume that they are no longer in an experimental stage and that while of course there will be refinements and further development, the fin furnace is at present a thoroughly reliable article of commercial merit, capable of producing immediate results in the matter of upkeep reduction and of lessening outage time due to present necessity of furnace-brickwork repairs.

When the finned tubes were applied at Hell Gate, prophecies were made as to the burning off of the fins, the erosion of the tubes, and the reduction of efficiency through too much cooling in the furnace. None of these prophecies has been fulfilled. The original boiler at Hell Gate has been in operation since December, 1923. The tubes and fins show no erosion, the corners of the fins being just as true and square today as when originally applied. The boiler has been in operation up to approximately 600 per cent of rating and efficiencies have been published from tests of these boilers which show as high as any that have been produced in the country, which would indicate that the losses due to excessive cooling looked for have not occurred.

Many attempts have been made in the past to water-cool furnaces. Most of the designs have embodied a combination of water tubes and brick, but the indications are that the complete metal furnace has several advantages over anything yet offered.

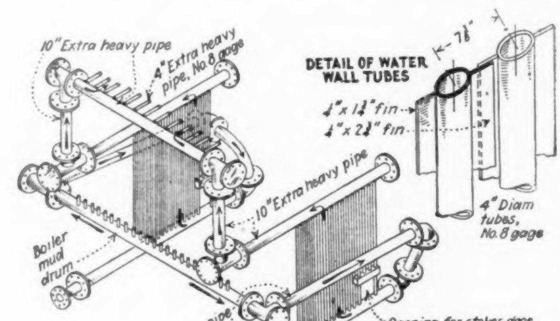


Fig. 1 Isometric View of Fin-Wall Furnace

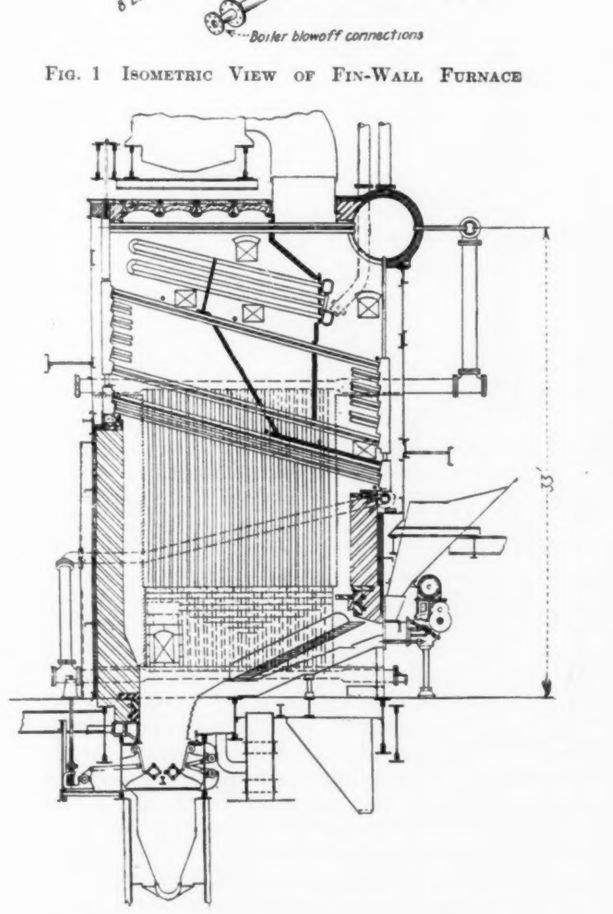


Fig. 2 Cross-Section of Fin-Wall Furnace and Boiler at Hell Gate

Welding of the fins to the tubes makes a complete bond, so that the transfer of the heat through the fins and tube is almost equal to the transfer through the tube itself. While no data are available at the present time covering actual results obtained, some tests are now being planned which will furnish data covering velocity, absorption, radiation, etc. We may, however, at present use as a comparison, some tests recently made on a Lopulco water screen

[1] Vice-Pres., Combustion Engrg. Corp., 43 Broad St. Mem. A.S.M.E.

Presented at the Second Annual Power Meeting, Chicago, Ill., Jan. 14 and 15, 1925, of the Chicago Section of The American Society of Mechanical Engineers.

at Cahokia, which indicate an absorption on the horizontal tubes of approximately 80,000 B.t.u. per sq. ft. and on the vertical side tubes of close to 75,000 B.t.u. per sq. ft. This would indicate that the vertical side tubes of the water wall have a very efficient absorption surface and that the cooling does not extend into the furnace a sufficient distance to interfere in any way with the efficiency of combustion. It has not been found that the capital expenditure required for fin-furnace construction is greatly in excess of the latest type of refractory furnaces. In fact, if credit is given for the additional heating surface gained, the cost chargeable to furnace will be slightly less than with other methods.

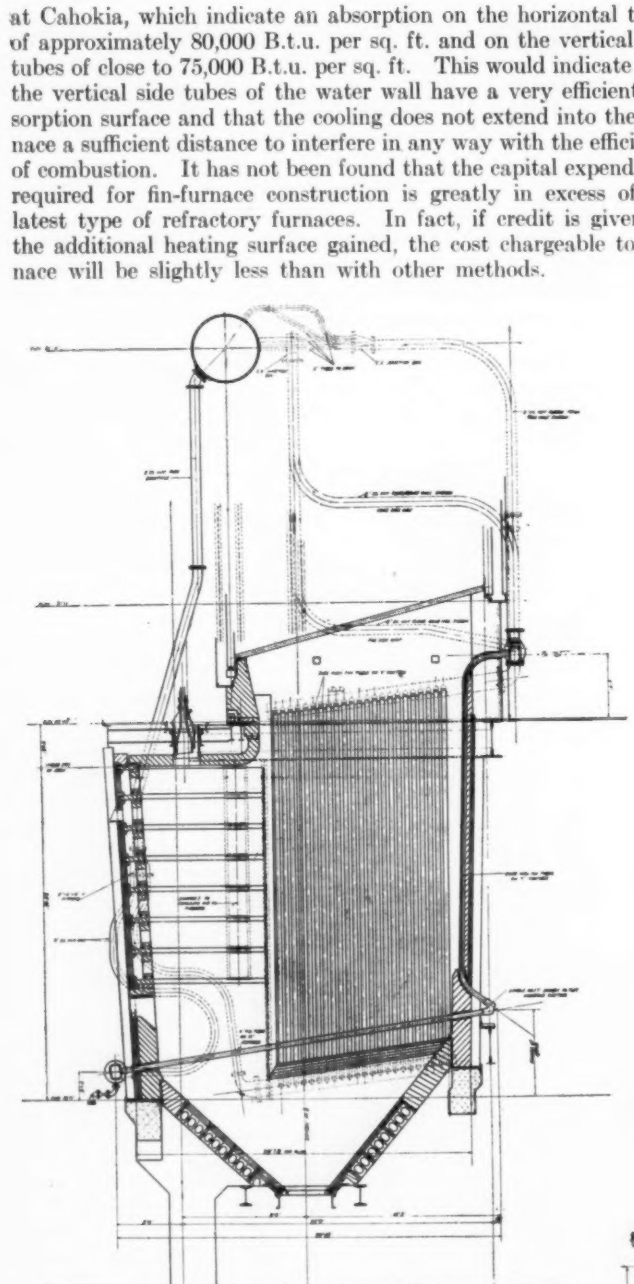


Fig. 3 Water-Cooled Furnace Combined with Air-Cooled Refractories

For the benefit of those who are not familiar with the furnace design, it may be well to briefly describe it.

Fig. 1 shows an isometric view of the screen installation at Hell Gate and Fig. 2 shows a cross-section of the same installation. These side walls consist of 4-in. tubes arranged vertically on each side of the furnace and spaced on 7-in. centers. Each tube has two longitudinal steel fins welded on it diametrically opposite each other, and when placed in the boiler furnace the fins overlap, thus presenting a continuous water-cooled surface to the radiant heat of the furnace. The lower portion of the tube is covered by fireclay tile for a short distance above the stoker. This extends along a horizontal line the entire length of the furnace. In future installations the refractory wall may be entirely eliminated and partially replaced with metal blocks.

The water in the tubes forms a part of the regular boiler circulation, the lower ends of the tubes being connected by headers leading to the mud drum. The upper ends of the side-wall tubes are connected to a header, which in turn discharges into the boiler drum through a special set of nipples and headers in front of the drum.

The water-cooled side walls not only replace practically all the brickwork in the side walls, but afford considerable protection to the front and rear walls by absorbing the heat which they reflect and thus lowering the temperature of the face of the wall.

To any one familiar with the difficulties of brickwork maintenance, the logic of the water-cooled walls is at once evident. Not only is the problem of brickwork maintenance in large boiler settings an item of considerable expense, but the loss of capacity of steam-generating equipment rendered idle by necessary repair periods is of even greater importance. In the older plants in which smaller boilers and furnaces are employed, it is not unusual to complete a major brickwork-repair job over a week-end or holiday period. With the larger settings several days are required, and each boiler represents a larger percentage of the total steaming capacity than it did in the older stations having a larger number of small boilers.

In days past, due to small units, the outage due to necessity for brickwork was not such a serious matter, and the necessities of stoker operation required considerable outage for stoker repairs and upkeep, so that brickwork maintenance might be done during these periods.

Now that the tendency is toward larger boilers and pulverized-fuel firing with the contingent ability to operate for long periods without the necessity for maintenance shutdowns caused by firing equipment, and since any outage on larger boilers must of necessity be for longer periods, it seems well to do away with the limiting factor which brick walls would naturally place upon such an installation.

Another tendency at the present time is toward preheating combustion air. Pulverized-fuel firing in combination with air heaters makes possible very high ratings and produces naturally very high efficiencies, which means a very intense heat in the furnace, making the necessity for water-cooled walls practically imperative. With water-cooled walls installed under such conditions, the units may be kept on the line for long periods without any more liability of shutdowns than is caused by the boiler itself under present conditions.

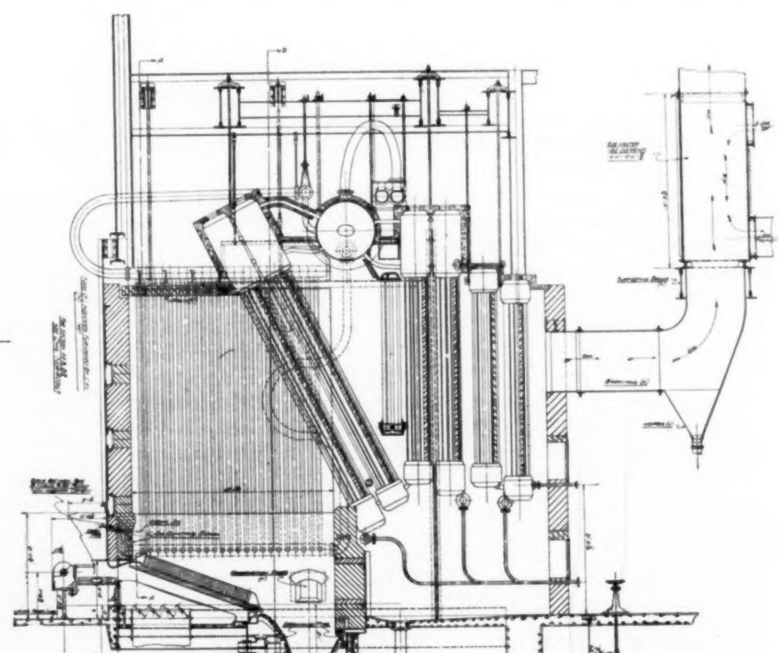


Fig. 4 Fin-Wall Furnace Applied to Bigelow-Hornsby Boiler

Fig. 3 shows the application of a water-cooled furnace in combination with an air-cooled refractories furnace now being applied

to one of the 1800-hp. boilers at Cahokia. It will be noted that considerably over half the side wall is screened as well as the back wall. It has been suggested by some that too much cooling may be obtained. All of the operation so far shows that there are no disadvantages from cooling as has been implied, and we know from experience that completely water-cooled furnaces, such as those of locomotives and Lancashire boilers, are used at very high ratings with excellent efficiencies.

Fig. 4 shows a combination of fin furnace and Bigelow-Hornsby boiler together with an underfeed stoker and air heaters. The fin furnace may be applied to any type of firing, either pulverized fuel, fuel oil, or stokers. It may be applied to existing plants on either large or small boilers and in many cases may be applied to present installations without making any changes in the settings, by simply installing the tubes in front of the present brickwork which would serve as a suitable backing and would practically end the necessity for the continuous patching and repairs which of necessity are being frequently made under present conditions if

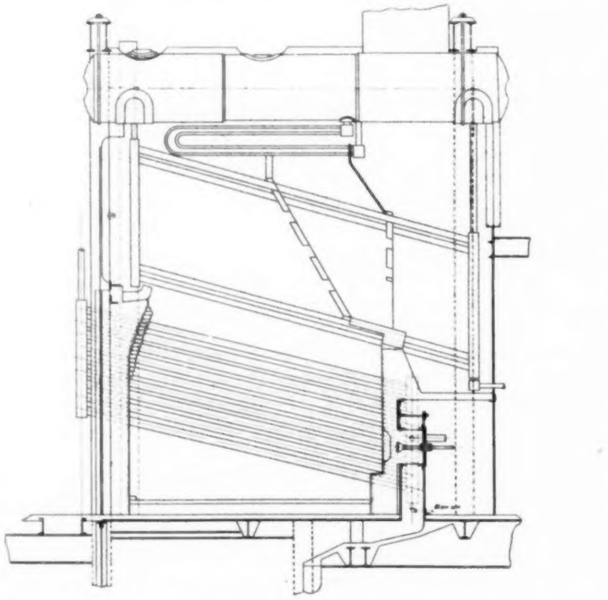


FIG. 5 APPLICATION OF A FIN WALL TO THE FURNACE OF A 600-HP. B. & W. BOILER

solid-wall furnaces are being used and any sort of efficiency or capacity is being obtained.

Fig. 5 shows such a suggestion for application to some 600-hp. B. & W. boilers where oil firing is used and where brick maintenance is naturally high at corresponding capacities. This application as shown was intended to be made without disturbing present furnaces, would cost but little more than the brickwork necessary at the time design was made, and would eliminate in the future this upkeep item.

We very frequently have engineers in charge of stations say, "Oh! well, I don't have much brickwork repairs and I wouldn't be justified in putting in water-cooled furnaces." This statement, if true, would only mean one thing, that a large capital expenditure has been made in order to operate boilers at a low rating in order to save brickwork, or that combustion efficiency is not what it should be.

The high cost of boilers and accessories and the proven ability of modern firing methods to produce high ratings for long periods with high economy have made obsolete rating methods of not more than a year ago, and the progressive engineer must discard his boiler-horsepower calculations and figure strictly from a standpoint of evaporation per square foot of heating surface and bear in mind constantly that the pounds of coal possible to fire efficiently under a boiler today bear no relation to his calculations of yesterday. This is most strikingly illustrated in the case of a new station projected for the eastern part of this country where the original figures made on the basis of underfeed stokers operating under the most favorable conditions showed a necessity for 44 boilers of approximately 15,000 sq. ft. heating surface each, and where the present figures revamped to cover pulverized-fuel firing, which has been apapted for this station, indicate a necessity for only 32 boilers of approximately 15,000 sq. ft. heating surface. The boilers, operating at the higher rating made necessary by the fewer number, will produce at the average rating at which they will be required to operate $62^1/_2$ per cent of the time 1.5 per cent higher efficiency than would have been possible with the 44 boilers at the lower average rating that would have been required. This consideration of modern equipment in this plant made a capital-investment reduction of approximately $4,000,000 on the boilers and boiler accessories alone, and this does not take into consideration the saving made in very high-priced real estate.

It is quite possible that in many plants where new boilers are contemplated, the addition of the fin furnace would permit much higher ratings and efficiencies, so that the purchase of the additional boilers might be postponed for several years to come.

Some question has been raised as to the effect the welding of the fins might have on the strength of the tubes. We have made numerous tests on finned and unfinned tubes and find that there is practically no reduction in the strength of the tube due to the welding of the fin. The author recently witnessed a hydrostatic test of a 4-in., No. 6-gage tube, 4 ft. long, on 2 ft. of which fins had been welded, the other 2 ft. being plain. The pressure was run up to 6000 lb. per sq. in. when a leak developed in the end plug, but no bulge or rupture occurred anywhere in the vicinity of the fins. The standard rupture test for a tube of this type is 6200 lb.

As stated in the beginning of this paper, it is not felt that there are sufficient data available at the present time to warrant the presentation of a technical paper on the fin furnace. It is believed, however, that this type of furnace is a practical operating proposition presenting opportunities for increased capacity, greatly reduced maintenance with equal, if not better, efficiencies, and has many other advantages such as reduction of outage, as stated before, and that where additional capacity is required in old plants no cheaper way can be found to produce it than through the application of fin furnaces to existing boilers. These few brief notes are offered with the hope that they may invite discussion and arouse the interest of the engineers present in this very successful and worthwhile engineering development.

Discussion

H. C. HEATON[1] said that his firm had always favored protection of the refractory material of their boiler settings and had tried for a number of years to get this developed, and he thoroughly agreed with the scheme worked up by the Combustion Engineering Corporation's engineers. His firm had tried it out in a little different way out at Calumet station, in that they had applied a water screen without the fins, and thus far, over a period of some nine months' operation, no trouble had been experienced from burning out of the tubes, and there had been no damage to the brickwork behind the tubes. As to whether the scheme would work out better with the fins or without, he did not know. He believed, however, that much the same results would be secured by the plain-tube surface.

G. E. Chamberlain[2] said that his company had recently purchased and were now installing two Edge Moor boilers of 897 rated horsepower each. One of these boilers would be operated at the beginning with a standard firebrick setting. The boiler beside it, under exactly the same conditions, would be operated with a water wall not of this but of competitive type. Just how much they would be able to secure from them he did not know, but Mr. Bailey thought he would be able to measure the actual evaporation under actual working conditions with the connections as would be considered standard from the mud drum and discharging steam to the steam drum. After those relative developments had been measured a water wall would be installed in the first boiler, which was originally a firebrick wall, and another series of comparative tests would be run. These comparative tests would be run probably over a period of months, not for just a few hours, and if it was

[1] M.E., Sargent & Lundy, Rm. 1412, 72 West Adams St., Chicago, Ill. Mem. A.S.M.E.

[2] Genl. Supt., A. E. Staley Mfg. Co., Decatur, Ill. Mem. A.S.M.E.

found then there was a difference they would be very glad to report all the results of their experiments.

C. W. E. Clarke[1] said that he had followed the water-cooled-wall development under consideration with a great deal of interest. Two years ago, in the Allegheny County steam-heating plant, his company had installed a rather large boiler, pulverized-fuel-fired, and due to the particular operating conditions, put in a water wall. It was a plain tube inserted in the firebrick and on $10^1/_2$-in. centers. The reason that led them to do that was the light load that this boiler was to run under through the summer time, and they felt that the air-cooled wall would get severe punishment with a very light flow of air. All of their expectations had been met. The boiler was now running through its second winter. They were installing a second boiler and had had no trouble other than, in early operation, burning out quite a few tubes, due to scale. That had been prior to getting the evaporation system into operation. Since that had been done they did not anticipate any trouble at all.

At the Colfax station they were running two pulverized fuel boilers with preheated air and water-cooled furnaces. There had been serious corrosion effects which would be corrected by fin boilers. He thought that with the use of preheated air the cooling of the walls artificially, other than by air, was absolutely necessary.

Alex. D. Bailey[2] said that the development of the big boiler and the high capacity had brought about a condition where something had to be developed to protect the furnace linings. Firebrick manufacturers had not been asleep, of course, but they had been limited by the materials with which they had had to work, and the materials had been punished by the ash from the coal which was being burned, so that while they had been able to get refractory materials that would on test stand temperatures far in excess of those encountered in furnace operation, these materials had failed under the influence of the molten slag with which they were continually washed.

The increasing high cost of fuel and the increasing cost of equipment had driven engineers and power-plant operators to the high-capacity boiler, with the attendant economizers and air preheaters in order to get the ultimate efficiency. The water screen, then, was a natural, or possibly a forced, development. Necessity was the mother of invention. The air-cooled wall had been tried in a half-hearted way, and had not proved successful. With preheated air it was out of the question. The pulverized-fuel furnace had probably been responsible for the introduction of water screens, and it had been proved that there was nothing to fear from the high evaporative capacities to which these tubes were subjected. Each one being a little bolder than the other, they had gone ahead and extended that surface until now a condition had been reached where the entire side wall was covered, not with firebrick, but with a heat-absorbing surface cooled by water. This development had probably gone along faster and smoother than most any other furnace development that could be recalled, and, as the author had indicated, great things were to be expected from it in the future.

John Hunter[3] said that he would like to ask what method the author had employed in determining the combustion temperatures in these large boilers with cooled walls, and what temperatures they were now working under.

The author, Mr. Savage, said that Mr. Heaton had mentioned the fact that his firm had combined brickwork and tubes. That was one of the steps, but why not go the full length and have a complete metal furnace? Brickwork was expensive to install; mason labor was high and not any too efficient today, and that complicated the arrangement considerably, and a year's operation on these boilers under the conditions at which they had operated at Hell Gate would certainly indicate that there was nothing to be feared from a completely water-cooled furnace. The fin tubes had been watched quite closely with the idea that the fins would burn off. One of the fins did burn, but it was the corner fin. These fins were $1^7/_8$ in. on one side of the tube and $2^7/_8$ in. on the other, which permitted them to overlap 1 in. They were not butted together in most instances. At Hell Gate they overlapped 1 in. with no physical connection between them, and this $2^7/_8$-in. fin on the end, which was against a brick pier, did burn off slightly, until it got back to where the water cooling prevented it, which was about $1^7/_8$ in., but that was the only deterioration there had been.

It had been quite interesting to hear Mr. Chamberlain tell of taking up the fin furnace in an industrial plant, for he had always looked toward the central station for a development of this sort. The industrial plant treated steam as a necessary evil, and it seemed to indicate a new era when the industrial man began to take up these developments and advanced ideas ahead of central stations.

Mr. Bailey had referred to the refractory manufacturers. It must be admitted, however, that the manufacturer of refractories was limited in the materials he had to work with. Good fireclays that were prevalent in the several districts where the high-grade clays occurred would stand perhaps 2800 or 3200 deg. in a laboratory, when not influenced by the sulphur, lime, iron, etc. that were encountered in fuels, and it had been found frequently that one brick would not stand up under certain conditions, while another from a district forty miles away would stand up perfectly under those conditions.

In answer to Mr. Hunter's question, temperature readings had been made with a water-cooled thermocouple straight across the furnace until a difference of 100 deg. had been found. The highest temperature encountered in one furnace was 2700 deg. fahr., probably where the flame had reversed itself. The temperatures had not been so great against the front or back wall, about 1500 deg. fahr. The temperature below the screen probably ranged from 1500 to 1600 deg. in these large furnaces. These conditions had again been verified at Brunots Island, where a temperature of 2800 deg. had been found. It was hoped later to make some investigation of that kind on a water-cooled furnace using preheated air.

Joseph Harrington[1] said that it seemed to him only one of three phases of the question had been touched upon. The author had referred exclusively to side-wall maintenance, as had the other experts. He would be very much interested in knowing if any consideration had been given by the author or his company to the greater utilization of the direct radiant heat from the incandescent fuel. It used to be thought that was a vital thing. Every one had tried to put a stoker in and he had noticed the difference in the efficiency. The locomotive, which had a completely enclosed water-cooled firebox, had developed some very remarkable efficiencies, considering the volume of the combustion chamber, due largely to the utilization of all of the radiant heat.

Mr. Harrington also asked whether or not the author had done anything toward making determinations on the reduction of side-wall radiation. It appeared to him that a large part of the total radiation of a boiler originated in the walls of the furnace proper. That must be very largely cut off and he was of the opinion that these two things would be vital factors in adding to the economy of this improvement.

The author, replying to Mr. Harrington, said that he would have to answer his question with a sort of alibi. It had, and it had not, been done. Some determinations had been made on a screen at Cahokia to see what was done by radiation and by contact, and those curves were not quite complete and ready for publication. The story would be very complete, because the length of flame travel had a good deal to do with it, and the spread of the flame throughout the furnace. He had not gone very far in that line in the stokers and water-cooled walls. At Sherman Creek, Mr. Murray had a water-cooled furnace, the tube or fin part being connected to a separate drum, and he expected to make some very elaborate tests that would cover the points suggested by Mr. Harrington. It was to be noted, however, that at Hell Gate there was considerable saving of the back wall and the front wall due to the absorption of the radiated heat by the screens and apparently there is some effect.

[1] Dwight P. Robinson & Co., 125 E. 46th St., New York, N. Y. Mem. A.S.M.E.

[2] Supt., Generating Stations, Commonwealth Edison Co., 22d and Fisk Sts., Chicago, Ill. Mem. A.S.M.E.

[3] Cons. Engr., Heine Boiler Co., St. Louis, Mo. Mem. A.S.M.E.

[1] Consulting Combustion Engr., Riverside, Ill. Mem. A.S.M.E.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Recent Developments in Tensile Testing

PROF. W. E. DALBY in studying the behavior of metals on removal and reapplication of load by means of his autographic load-extension recorders has shown that metals possess elastic properties right up to fracture. Up to a certain limiting stress the extension is proportional to the applied load. When the stress is exceeded the metal loses its proportional elasticity but retains the property of non-proportional elasticity. When the metal has passed into the condition of non-proportional elasticity the removal and reapplication of the load causes a loop to be traced in the recorded load-extension diagram.

The loops obtained from different metals have distinguishing characteristics and Professor Dalby has shown that the loop area increases with permanent set, and that loop area plotted against permanent set gives a smooth curve. This will be referred to as the "normal curve" for a metal. The researches described here were undertaken with a view to investigating the factors influencing the formation of these loops and to studying the effects of variations in composition and treatment of metals on the looping properties with special reference to tests on steel.

Fig. 1 shows three typical loops. They were obtained in a test

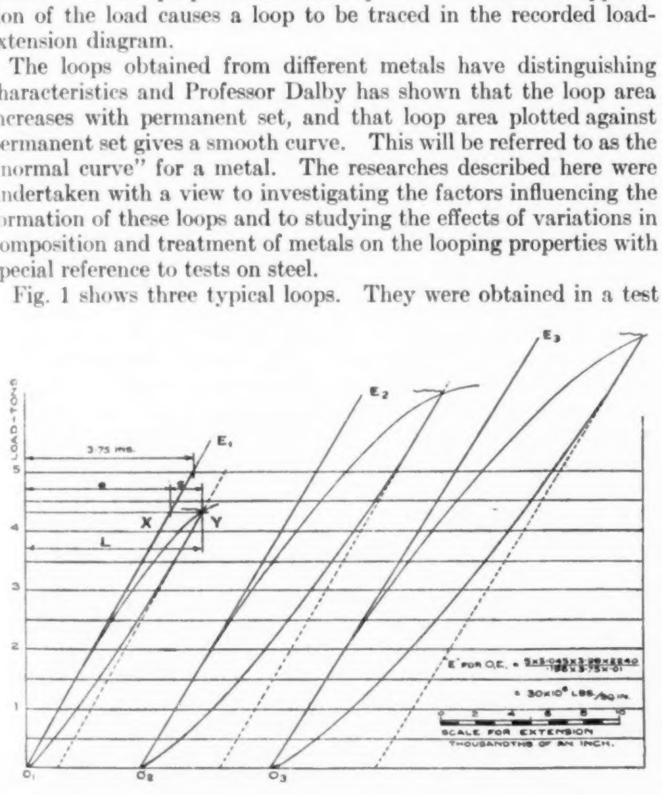


FIG. 1 LOOPS OBTAINED WITH DALBY LOAD-EXTENSION RECORDER ON A STEEL CONTAINING 0.63 PER CENT CARBON

on a steel containing 0.63 per cent carbon. The lines O_1E_1, O_2E_2, and O_3E_3 have been drawn in on the diagram at a slope corresponding to the primitive modulus of elasticity determined from the elastic line at the beginning of the record. The loop boundaries are curved, and this causes the loops, as a whole, to slope away from the E lines.

Referring to the first loop, on the application of the load, the spot of light which traces the record on the photographic plate moves from O_1 along the curved path O_1Y. This motion can be regarded as compounded of:

1 A movement from O_1 to X in the direction of the primitive elastic line, producing an extension marked e in the figure; and

2 A plastic step or slip, XY, parallel to the extension axis, producing a further increment of extension s in the figure.

The total stretch of the test piece at the top of the loop is thus made up of a proportionally elastic portion and a non-proportionally elastic portion. The remarkable fact is that, on unloading the test piece, the spot of light traces out a similar curve; so that not only the proportionally elastic but also the non-proportionally elastic component of the extension disappears.

For want of a more suitable name, it is proposed to call this non-proportional component of the curved loop boundary the "recoverable slip." The question which immediately arises is: What is a convenient measure of recoverable slip?

From the analysis of the curved loop boundary into two steps, namely, a primitive elastic straight-line step and a plastic step parallel to the axis of extension, it is clear that the greater this second step the further will be the departure of the loop boundary from the primitive elastic E line. Numerous experiments have indicated that the greater this departure—or recoverable slip—the greater is the curvature of the loop boundary and, consequently, the area enclosed when the load is removed and reapplied.

It has been found that for a given material when the load and extension have been reduced to the corresponding values of stress and strain the length of the second plastic step depends only on the stress and is independent of the cross-section of the test specimen.

The authors come also to the conclusion that the recoverable slip produced by a given stress, and therefore the curvature of the loop boundaries, is an inherent physical property of the metal. It follows from this that the main width of a loop will depend only on the stress at the top of the loop, whatever the diameter of the test piece.

A series of tests on looping at constant load were made. It was found that the total elongation was the same whether the test piece was broken by a continuous pull or by constant-load looping at the higher or lower load. The deduction is that the ultimate cause of rupture is permanent set or plastic deformation, and not the total amount of work expended in producing this deformation. Further tests would indicate that when a loop is traced an internal disturbance is set up in the metal, which is a cause of the production of permanent set and therefore, ultimately, of rupture.

Recoverable slip is measured by mean loop width. For the large number of steels tested, it was found that the characteristic curves of mean loop width plotted against stress were substantially parallel. Thus, by selecting a convenient arbitrary value of mean loop width, the corresponding value of stress can be read off the characteristic curve. This stress provides a means of comparing different steels as regards that property of the metal which is revealed by this method of testing.

A mean loop width of 0.0015 in. was found to be a convenient value for test pieces of 5 in. gage length; and the quality factor of a steel is therefore defined as the stress in tons per square inch necessary to produce this standard loop width. A steel having a low quality factor will be characterized by large loops, and conversely.

The comparison of different steels by means of the quality factor defined in the last paragraph yields remarkable results. Fig. 2 records the factors derived from tests on two series of carbon steels. The carbon contents ranged from 0.16 per cent to 0.83 per cent, and the two series differed only in the amount of phosphorus present. This was 0.03 per cent in one series and 0.11 per cent in the other.

Each series was subjected to two heat treatments before testing, one a simple anneal and the other a complete treatment consisting of quenching followed by reheating. There are thus four groups of tests.

The influence of carbon content on quality factor appears to depend on the heat treatment which the steel has undergone. For low-carbon steels there is little difference in the factor whether this has been a simple anneal or a complete double treatment. But with heat-treated steels the factor rises with the carbon and reaches a maximum at about 0.6 per cent carbon, while for annealed steels it falls with rise in carbon content. The annealed series is incomplete, as the higher-carbon members were so brittle that they were liable to break suddenly with very little permanent set. To avoid

risk of damage to the delicate extensometer mechanism, tests on these steels were postponed; but there are indications that the quality factor has a minimum value at 0.6 per cent carbon, exactly where the maximum value of the factor occurs in the case of heat-treated steels.

As regards alloy steels, no change in quality factor could be detected with variations in nickel up to about 3 per cent. Nickel-chrome steels, containing between 0.8 and 1.2 per cent chromium, after correct heat treatment, had a factor 1.6 times that of a straight-carbon steel of the same carbon content.

Looping tests on the series of steels referred to above showed that variations in carbon content have practically no effect in annealed steels containing 0.11 per cent phosphorus. The elastic limit over the whole range of carbon content was 21 tons per sq. in.

Reduction in phosphorus content to 0.03 per cent was accompanied by a lowering of the elastic limit. This was more pronounced

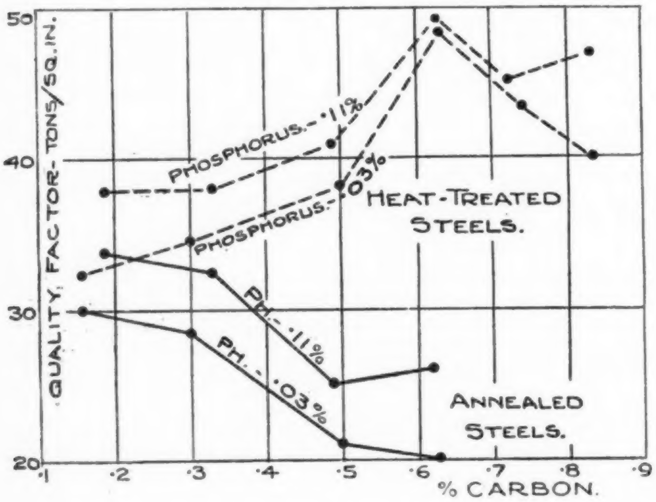


FIG. 2 VARIATION OF QUALITY FACTOR WITH CARBON CONTENT

at the low-carbon end of the range, so that the limit rose from 12 tons per sq. in. for steel containing 0.1 per cent carbon to 18 tons per sq. in. for that containing 0.9 per cent.

The elastic limit of the sorbitic heat-treated steels rose more or less uniformly with the carbon content, varying from 18 to 30 tons per sq. in. over a carbon range from 0.1 per cent to 0.9 per cent.

Variations in nickel up to 3 per cent were found to have no influence on the elastic limit of steel containing 0.15 per cent carbon. When present to the amount of 4.7 per cent, nickel appears to produce a profound change in the character of the metal. This is indicated by a fundamental departure from the typical steel load-extension diagram. The irregular yield link is suppressed and there is a smooth transition from the elastic line to the curve of plastic extension. This change in the metal was accompanied by an elastic limit having the exceptionally low value of 9.1 tons per sq. in. (annealed) and 12.1 tons per sq. in. (heat-treated).

Tests were also made to determine how steels of certain compositions and heat treatment recover their property of proportional elasticity with time; the periods of rest having varied up to three months. The conclusions drawn from these tests were:

1 Annealed (pearlitic) hypoeutectoid steels, including pearlitic nickel steels, completely recover their property of proportional elasticity with rest. The limit of proportional elasticity after rest is the maximum load previously applied.

2 Sorbitic (heat-treated) carbon steels of all compositions have no such power of recovery. On reloading after rest, the load-extension line was curved and a loop was traced on the removal of the load.

3 Carbon steel of eutectoid composition does not recover, whatever its previous heat treatment.

It would appear also that the normal curve of loop area plotted against permanent set indicates the heat treatment which the steel has undergone. Such a normal curve consists of three parts corresponding to the three stages in the complete tension test, of which the first is the yield point in which a large extension takes place while the load fluctuates about a constant value, and the second, the period of plastic elongation subsequent to the yield period. For the second stage in the test the logarithmic curve is sensibly a straight line and a simple approximate relation appears to exist in the form

$$\text{loop area} = \text{constant} \times (\text{permanent set})^n$$

and the lines for the steels tested and plotted are mutually parallel. The index n has the value of 0.65 whatever the carbon and phosphorus content. From tests on heat-treated sorbitic steels it would appear that the index is 0.40. The index is therefore a criterion as to the heat treatment to which the steel has been subjected. (Dr. J. V. Howard and Dr. S. L. Smith in *Proceedings of the Royal Society, Series A*, vol. 107, no. A 741, Jan. 1, 1925, pp. 113–125, 9 figs., *etA*)

Short Abstracts of the Month

AERONAUTICS (See also Physics: Skin Friction)

A Giant Junkers Plane

A FRENCH publication, *Ephémerides de l'Aéronautique*, reports news of a giant Junkers plane designed along totally new lines, of which a scale model about 12 ft. in length was shown at the last Universal Postal Congress in Stockholm. The full-size machine is to be a monoplane of 250 ft. span with a wing 20 ft. thick. The power plant will consist of six 1000-hp. engines mounted inside the wing at its trailing edge. The engines will be of Diesel crude-oil type and will drive turbines by means of compressed air. These turbines will be located at the leading edge of the wing. The elevators and rudders will be situated in front of the wing, inside of which all loads will be located. The Junkers engineers insisted particularly on the fact that the scale-reduced model of this ship had already been flown and found satisfactory and that the new system of propulsion had also come up to expectations. (*Aviation*, vol. 18, no. 4, Jan. 26, 1925, pp. 104, *g*)

AIR ENGINEERING

An Experimental Study of Fan Evasees

A PAPER based on experimental work carried out at the Heriot-Watt College, Edinburgh. Among other things, the authors found that under the most favorable conditions an évasée may operate with an efficiency of 80 per cent; an évasée expanding equally on all four sides is at its best more efficient than one expanding on two sides only, though when the angle exceeds about 11 deg. the latter type may be more efficient than the former; the chimney with four equally hading sides should have an angle not less than 5 deg. and not more than 9 deg., i.e., the hade on each side should be between $2^1/_2$ and $4^1/_2$ deg.; the chimney expanding in one direction only should have an angle between 8 and 14 deg.; the loss of energy within a straight-sided évasée of (almost) the best angle takes place principally at the narrow end, which makes the shape of the chimney at its throat and the conditions under which the air enters especially worthy of attention. A funnel of 7 deg. apical angle ($3^1/_2$ deg. hade) proves superior to the others, and even an ill-designed evasée is better than none.

The author discusses the design of existing évasées and the energy available for conversion by évasées and proposes a design claimed to enable a full four-to-one expansion at 7 deg. to be realized even when the throat is large, and this without the need for building a large vertical chimney. Such an évasée is shown in Fig. 1. The greater portion of it is horizontal and is made by trenching from the surface; the walls and roof of the passage may be supported by concrete. There is no grave objection to the right-angled turn as it occurs where the speed of the air is low. It is possible to arrange a horizontal évasée on the prolongation of the fan drifts (instead of returning between them as illustrated) by providing a bypass round the fan for reversal.

Évasées should be given serious attention because there is reason to believe that the weight of air passing through British mines is, on the average, about 5.8 tons per ton of coal raised; also that the

average water gage is somewhere about $3^1/_4$ in. If the average fan plant be credited with an overall efficiency of 45 per cent, it is easy to show that an increase of 1 per cent in average overall efficiency represents, for the whole country, a saving of 200 hp. which, at $^1/_2$d. per kw-hr., represents an annual reduction of over £27,000 in cost of power. If, by attention to the mode of discharge of the air into the atmosphere, an improvement of 3 or 4 per cent can be secured at one place and 6 or 7 per cent at another, the financial saving effected becomes especially worth attention.

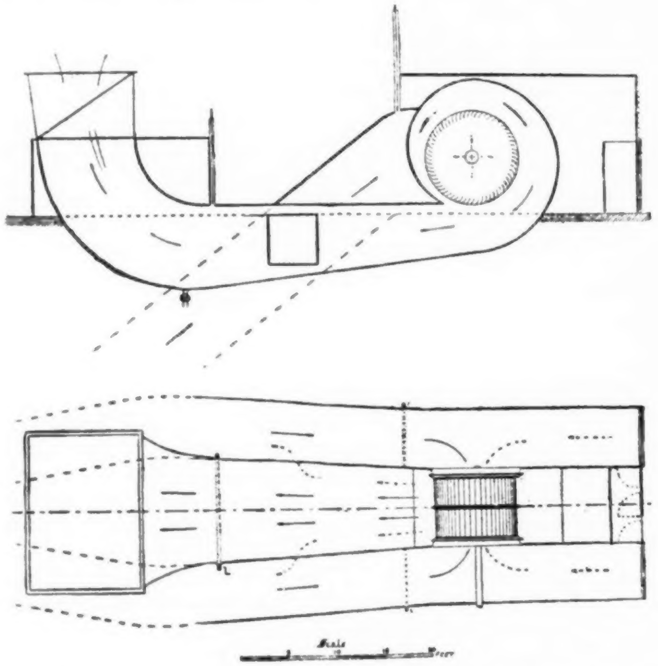


FIG. 1 PROPOSED DESIGN OF FAN EVASÉE OF 4-TO-1 EXPANSION NOT REQUIRING LARGE VERTICAL CHIMNEY

(Prof. Henry Briggs and J. M. Williamson in a paper read Dec. 13, 1924, before the North of England Institute of Mining and Mechanical Engineers at Newcastle-on-Tyne, and abstracted through *The Iron and Coal Trades Review*, vol. 109, no. 2965, Dec. 26, 1924, pp. 1044–1045, 6 figs., *dg*)

CONSTRUCTION

Under-Water Bridge between France and England

AFTER extended consideration the British Parliament has refused its consent to authorize the construction of a railroad tunnel between France and England, considering that this might prove inimical to the interests of national defense. Commander J. Veyrier therefore proposes another solution of the problem which he believes may prove acceptable to the English, namely, the installation of two parallel submarine tubes supported by concrete piling at the bottom of the channel. The tubes themselves are to be made of reinforced concrete.

The depth of the channel at the spot selected for the installation does not exceed 55 meters (180 ft.). The tubes would be located at a depth of only about 20 meters (65 ft.) below the sea level. Because of this there would be no interference with navigation and at the same time the tubes would not be subjected to excessive hydrostatic pressure. It is intended to make each tube of an internal diameter of 5 meters (16.4 ft.) and in order to give the tubes a weight such as to make their buoyancy equal to zero, the walls would have to have a thickness of 0.70 meter (2.29 ft.). Now, even a tube of 5 meters (16.4 ft.) internal diameter with a wall thickness of 30 cm. (11.8 in.) is capable of resisting the external pressure due to immersion to a depth of 20 meters (65 ft.). Such a tube has, however, a buoyancy of 12 (metric) tons per running meter. In order to bring the buoyancy down to 3 tons per running meter, its weight has to be increased by 9 tons per running meter. In part the weight of the track will do this, and for the rest the thickness of the tube walls will be increased so as to increase the resistance of the tube to bending and accidental shocks, such as might result, for example, from its being hit by an anchor. As shown in Fig. 2, the tube will be given a lentil-like cross-section. In this way the thickness along the axis will be materially increased and the resistance of the tube to the action of the objects falling from above improved. Each section of the tube is designed to be 200 meters (656 ft.) long, a dimension which is supported by practice in similar land installations in navy yards. This means that it will be necessary to put in 175 piles, each pile weighing in the neighborhood of 600 tons. Some details as to the proposed design of the installation are given in the original article. (*Le Génie Civil*, vol. 86, no. 1, Jan. 3, 1925, pp. 19–20, 7 figs., *d*)

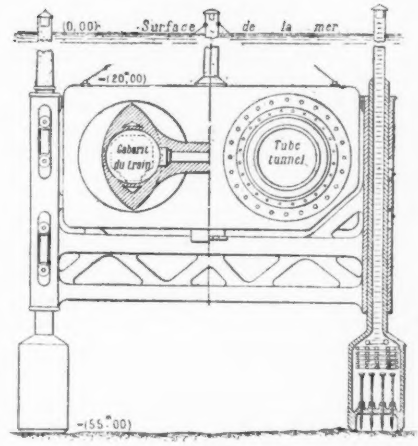


FIG. 2 PARTIAL CROSS-SECTION OF THE PROPOSED VEYRIER SUBMARINE TUBULAR BRIDGE BETWEEN FRANCE AND ENGLAND

CONVEYING MACHINERY

Longest Belt Conveyor in the World

DESCRIPTION of an installation at Clairton, Pa., of the H. C. Frick Coke Co., a subsidiary of the U. S. Steel Corporation, installed to deliver coal to by-product coke ovens. The system is handling upward of 9000 tons per day. The control is practically automatic and the labor involved in operation, maintenance, and supervision is extremely small. The power consumed amounts to about 0.363 kw. per 100 tons per 100 ft. level or equivalent.

The belt is $4^1/_2$ miles long, 8-ply, 32-oz. duck, $^3/_{16}$-in. rubber-covered, except in two cases where fabric belts are used. The drive and head pulleys are 48 in. in diameter, mounted on $7^1/_2$-in.-diameter shafts with split hubs. The shafts are carried in roller bearings and are fixed in accurate alignment. Snub and tail pulleys are 36 in. in diameter, on $5^1/_2$ in. shafts with smaller bearings. The lubricating grease is forced into reservoirs in the pulleys at high pressure. The belt, troughed as it carries the coal, returns flat, carried on simple pulleys properly spaced beneath the structure. (*Chemical and Metallurgical Engineering*, vol. 32, no. 4, Jan. 26, 1925, p. 159, 2 figs., *d*)

ENGINEERING MATERIALS (See also Machine Parts: Strength of Wire Ropes)

Pure and Mixed Electrically Fused Alumina Cement (Sand Cements)

SINCE 1920 the Société de Fonte Electrique at Bex has been making an electrically fused alumina cement sold under the trade name of Electrociment. This product is made in accordance with the formula of a French chemist, Bied, and has been applied in a number of cases in Switzerland. Its advantages lie in its high mechanical strength, quick hardening (two to three days), and ability to resist the action of waters containing selenium salts. The article describes, in particular, an installation on the Magnacun tunnel on the Engadine Line and the use of the cement on a gas holder at Villeneuve. The experience collected in the course of these two works have given a clear idea as to the properties of this material. Among other things, it is stated that the price of the material is still quite high. There are a number of instances where conditions do not justify the use of a full proportion of the cement, and the author discusses to what extent it may be mixed with cheaper materials and still retain the most desirable properties. It is found that a mortar may be compounded costing 68 per cent of what pure cement does and retaining 56 per cent of the strength of the latter.

It would appear, therefore, that the new cement may be usefully employed where high mechanical strength has to be attained within approximately 72 hr. after pouring and where it is important to have a material capable of resisting sulphates and magnesium salts. (A. Paris, Professor at the University of Lausanne, in a paper before the London Congress of Constructing Engineers, April, 1924; *Bulletin Technique de la Suisse Romande*, vol. 50, no. 25, Dec. 6, 1924, pp. 309–312, 2 figs., *d*)

Cellular India Rubber Insulation

A report of the Engineering Committee of the Food Investigation Board (Great Britain) dealing with the subject of heat insulators, gives some figures regarding the property of cellular india rubber produced from rubber expanded by means of gas under pressure.

The specific conductivity of cellular rubber was found to vary from 0.00009 to 0.00012 C.G.S. units, as compared with 0.00011 for equivalent insulators, but whereas the latter weighed from 11 to 13 lb. per cu. ft. the former weighed 5 to 7 lb. per cu. ft. in the samples examined. It is to be noted that this conductivity is still considerably higher than that of still air, which is given as 0.00005 C.G.S. unit. While, however, as regards weight, a substantial saving could be obtained by the use of this material, it is obvious that for the same degree of protection the thickness of the insulating walls would have to be made the same as at present, and there still remains the very important question of durability under rough usage and chemical stability which remains to be further investigated. (Editorial in *Shipbuilding and Shipping Record*, Special Number, Jan. 7, 1925, pp. 1–2, *g*)

Scleron Alloys

These belong to the class of aluminum alloys that are capable of being hardened. In addition to the usual constituents such as copper, nickel, zinc, manganese, and silicon, some of these alloys contain lithium. The total of the alloying elements varies from 5 to 15 per cent. The action of lithium is comparable to that of magnesium in duralumin. The melting point of scleron alloys varies in accordance with the composition but does not go below 600 deg. cent. (1112 deg. fahr.)

In service scleron alloys should not be heated above 200 deg. cent. (392 deg. fahr.) as this destroys the properties given them by heat treatment. Untreated material has about 50 per cent of the strength and hardness of treated material, but the elongation is not so much affected by the heat treatment. The original article gives the main properties of scleron alloys, from which it would appear that alloy No. 1 has a tensile strength of 40 kg. per sq. mm. (57,000 lb. per sq. in.) and an elongation of 10 per cent, and alloy No. 2 a tensile strength of 36 kg. per sq. mm. (51,000 lb. per sq. in.) and an elongation of 20 per cent. Alloy No. 1 has an elastic limit of 20 kg. per sq. mm. (28,500 lb. per sq. in.) (Dr. of Engrg. O. Reuleaux in *Zeitschrift für Metallkunde*, vol. 16, no. 11, Nov., 1924, pp. 436–437, 1 fig., *d*)

FUELS AND FIRING (See also Marine Engineering: Oil Fuel for Motorships of Tomorrow)

The Oehm Heating Unit

An apparatus for the production of heat from solid fuel has been placed on the market by International Processes, Ltd., Basildon House, Moorgate, London. It is claimed that any apparatus used for the production of heat should be entirely dependent of the object or container to which the heat is applied. The Oehm heating element is said to effect the complete combustion of solid fuel to carbon dioxide gas possessing pressure and velocity without flame and smoke. The element has two compartments, one containing the fuel and being so constructed that air can only enter through the fire bars, and must all pass through the bed of hot fuel. This air is aspired by the suction caused by a single small jet of preheated compressed air at a pressure of 70 to 80 lb., situated at the top of the second compartment. The second compartment contains a coil of tubing, in which the compressed air is preheated, and a system of louvered firebricks. The air entering the first compartment is carburized to carbon monoxide; it is then drawn over the fire bridge by the fine jet, and, mixing with the incoming compressed air, impinges with considerable velocity over the large area of highly incandescent, specially shaped firebrick, forming carbon dioxide, which issues from the orifice at the bottom at a temperature of from 1400 to 1600 deg. cent., or about 2550 to 2800 deg. fahr., with considerable pressure and velocity. These hot gases are then led directly into the space in which they are needed, filling it and maintaining a considerable pressure. The temperature of the gases themselves can be regulated within limits by regulating the air supply. When once the heating element has been well started by the use of wood and solid fuel, any kind of breeze or rubbish can be burned with additions of better fuel. The elements are made in three sizes; the smallest uses 16 lb. of coke per hr. and produces 165,000 B.t.u. per hr. Air at a pressure of 70 to 80 lb. per sq. in. is required, the volume being 317 cu. ft. The largest size produces 560,000 B.t.u. from 56 lb. of coke per hr., 847 cu. ft. of free air at 70 to 80 lb. per sq. in. being required. The element is exceedingly well adapted for drying molds and cores on the floor, in pits and in drying rooms, for heating ladles, shanks, and ingots, and for annealing and heat treatment generally. The unit has been installed in several steel works and other plants. (*Machinery*, (Lond.), vol. 25, no. 642, Jan. 15, 1925, p. 504, *d*)

Automatic Kiln Stoker

The great difficulty involved in the operation of a kiln stoker is its small capacity, which is about 150 lb. of coal per hr. as a maximum. Kiln stoking requires a number of small units operating together and such operation presents the problem of so joining and driving these units that the expansion of the kiln and the stoker setting will not bind or cramp the operation of the individual stokers or their driving mechanism. An important part of the kiln-stoker problem is to provide the necessary flexibility of the driving mechanism and the connection with this to the stokers themselves so that any change in the position of the stoker settings is automatically taken care of. In addition to this, it is necessary that the stoker should be so connected to the driving mechanism that in case its operation is temporarily interfered with, it can be shut off and the other stokers can continue operation. Because of this a somewhat novel type has been designed in preference to attempting the adoption of any existing industrial stokers to these conditions.

A real automatic stoker is not only a coal-feeding device, but it will keep the fuel bed in a uniform condition because it keeps it moving uniformly from the time it enters the furnace as coal until it is discharged as ash. To keep the fuel bed in this condition is well worth while because the problem is not merely to burn coal in the furnace, but to get the heat from this burning coal circulated through the ware from the top to the bottom of the kiln. A coal-feeding device which has first a comparatively thin fire on the grate which thickens and becomes dirty as more and more fuel is fed in, is gradually choking off the circulation through the fuel bed and the kiln. With such a varying condition of the fuel bed, the rate at which it will burn the fuel is constantly changing, as a clean thin fuel bed will burn coal faster and liberate more heat. There was the usual objectionable loss of heat experienced when cleaning kiln fires by hand.

After firing a number of kilns of face brick in 1921 with these coal feeders it was determined to change them to real stokers. The first designs were not satisfactory, but ultimately the problem was solved by the employment of a rotating round grate having the fuel fed to it from the center from below. The grate is not flat but raised in the center so that it is approximately the shape of a cone. When the kiln is on high fire the grate is rotated once in about 30 min. and the ashes are taken off its outer edge continually by a scraper. It is stated that means for rotating the grate have been developed which do not employ either shafting or gears on account of possible warping of the parts. A method of automatically removing such siftings as actually fall into the wind box has also been designed.

According to the author, material benefits have been secured, as the time of firing was shortened from an average of $7^1/_2$ days for hand-fired kilns to $5^1/_2$ days, and moreover the stoker can handle poor grades of coal.

In answer to questions in the discussion it was stated that each stoker takes one-tenth of a horsepower to drive it. The subject of clinker formation and clinker trouble was also taken up in the discussion. (John D. Martin, Straitsville Impervious Brick Co., New Straitsville, Ohio, in *Journal of the American Ceramic Society*, vol. 7, no. 12, Dec. 1924, pp. 878–884 and discussion pp. 884–888, *d*)

HYDRAULICS (See also Mechanics: Bursting Forces Acting on Walls of Pipes)

A New Theory of Fluid Flow

IT is believed fairly generally that when a fluid "wets" a pipe a thin film of unknown thickness clings to the wall and does not move with the rest of the moving fluid. The only curve known which will represent the condition of the fluid across the entire diameter of the pipe and yet account for the existence of this stationary film is the logarithmic curve whose equation is

$$y = ae^{bx} \qquad [1]$$

where a is the thickness of the stationary film and b a constant multiplier of the velocity. The author considers next velocity distribution for water flowing full in an open channel of rectangular cross-section, the channel being assumed to be so wide that the side walls do not exert any appreciable effect on the velocity distribution at the vertical section shown in Fig. 3. If the bottom O_1X of the

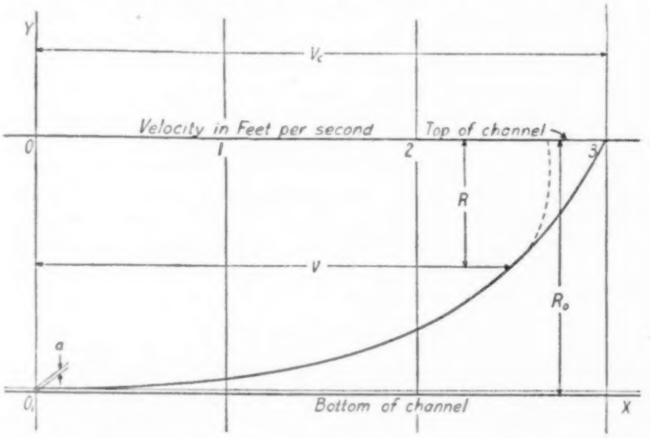


FIG. 3 FLUID-FLOW VELOCITY-DISTRIBUTION DIAGRAM FOR DERIVATION OF FORMULA FOR VELOCITY-DISTRIBUTION CURVE

channel were incapable of retarding the layer of fluid lying next to it, this layer would of course move as fast as the fluid in the body of the channel, and the velocity distribution curve would be a straight line parallel with OY. But since the layer of fluid is held back by the bottom of the channel, this layer cannot move as fast (it probably does not move at all, except by diffusion) as the layers which are farther away from the bottom and which are therefore not so much affected by it. Due to the viscosity, or internal friction of the fluid, the layer of fluid next to the bottom of the channel exerts a retarding force on the layer of fluid next above it; this second layer retards or accelerates only the air above it. If the air is stationary, or if it is moving in a direction opposite to the direction of flow of the water, the velocity distribution curve will be "hooked" backward, as is shown in dotted line in the figure. (See curves on p. 253 of Unwin's Hydraulics.) For the sake of simplicity the wind will be assumed to be blowing in the same direction as that in which the water is flowing and with the same surface velocity V_s, so that it exerts neither a retarding nor an accelerating force on the water. The upper layer of water will therefore be retarded only by the layer of water next below it.

Now the energy for retarding all the layers of fluid from the bottom to the top layers is furnished by the action of the bottom of the channel on the bottom layer of water. All the energy for retarding all the other layers of water has to be transmitted by this bottom layer to the layer of fluid next above itself; this second layer has to transmit all the remaining energy for retarding the rest of the layers above itself, and so on until the next to the top layer is reached, which has to transmit only the energy that retards the top layer. In order to transmit this relatively greater amount of energy, the lower layers of the fluid are displaced relatively to one another to a greater and greater extent as the bottom layer is approached. Under simple, perfect conditions of flow, the relative difference in velocity between layers would be inversely proportional to the distance of the layers being considered from the bottom of the channel. Expressed mathematically,

$$dy/dx = by \qquad [2]$$

where b is a constant. Arranging [2] for integration,

$$dy/y = bdx \qquad [3]$$

Integrating,

$$\log y + c = bx \qquad [4]$$

Solving for c,

$$c = bx - \log y \qquad [5]$$

When

$$x = 0,\ c = -\log a \qquad [6]$$

Substituting this value in [4],

$$\log y - \log a = bx \qquad [7]$$

Combining terms,

$$\log (y/a) = bx \qquad [8]$$

Expressing exponentially,

$$y/a = e^{bx} \qquad [9]$$

Clearing of fractions,

$$y = ae^{bx} \qquad [1]$$

From Fig. 3,

$$y = R_0 - R \qquad [10]$$

and

$$x = V \qquad [11]$$

Substituting these values in [1],

$$R_0 - R = ae^{bV} \qquad [12]$$

In order to show how closely the curve whose equation has been developed corresponds to actual flow conditions, the points from various velocity distribution curves obtained by various experimenters have been plotted in figures in the original article, but instead of drawing in the curves which these experimenters did, a logarithmic curve with the constants that best average has been substituted. Although the curves shown cover experiments with such varied fluids as air, water, and light and heavy oils, the theoretical curves fit the experimental points remarkably well. In some cases the point of maximum velocity does not lie on the center line of the pipe, but this is more or less accounted for.

The curve has been drawn for the purpose of making clear the development of formulas for average velocity of flow and for friction loss. This is a diagrammatic representation of the fluid distribution of a fluid flowing through the center velocity of 3 ft. per sec. through a long, smooth, straight pipe of circular cross-section. The relations of a and b in the general formula of the logarithmic curves are here worked out and expressions for the two are given. It is found that b depends for its value on V_c (maximum velocity of flow at center of pipe in feet per second) and upon m [where $m = 1 \div (1 - V_m/V_c)$ and V_m is the velocity of flow at a point half-way between the center line and the wall of the pipe]; a depends for its value on the ratios of the pipe r_0 and upon m, while this latter is dependent for its value only upon the ratio V_m/V_c. Tables in the original article show that the value of the ratio V_m/V_c is different for different sizes of pipes and possibly also for different velocities of flow. The value of the ratio for a given fluid is probably dependent on the known or determinable characteristics of the fluid such, for example, as density and viscosity. Curves are given in the original article to show the practical importance of temperature in water flow tests.

A formula is next determined for average velocity of flow as well as what the author claims to be a more exact formula for friction loss. For air and other gases the author expresses friction loss in terms of pressure. The formulas check quite well with experimental data available. The following possible uses of the theory are suggested: It makes possible the development of fluid flow form-

ulas applicable to the flow of all kinds of fluids. Next, it opens up a way for the complete practical solution of the centrifugal-pump problem as well as furnishes a method of investigating the action of pumps, fans, propellers, water wheels, steam turbines, etc. It also provides a more accurate method of calibrating pitot tubes, especially for certain velocities of flow. A bibliography of the subject is appended to the article. (Anthony Bruce Cox in *Journal of the Franklin Institute*, vol. 198, no. 6, December, 1924, pp. 769-793, *tA*)

LUBRICATION

Friction of Pistons and Piston Rings

RECENT investigations carried out at the National Physical Laboratory for the Lubrication Research Committee of the Department of Scientific and Industrial Research have indicated that in the lubrication of surfaces in which the relative motion is of a reciprocating nature, as distinguished from the unidirectional motion of a shaft journal, the surfaces, as would be expected from theoretical considerations, are not in general separated by a film of the lubricant of sufficient thickness for the ordinary theory of lubrication to be applied to it, but the condition is that which has been denoted by Mr. W. B. Hardy as "boundary lubrication," i.e., the distance between the surfaces is of molecular dimensions. In this condition the resistance to the motion follows the well-known laws of solid friction, the resistance being proportional to the load and independent of the speed.

In the experiments on the cylindrical bearings of heavy pendulums described in *The Engineer* for June 29, 1923, these laws were found to be accurately followed, and it was found possible to obtain considerable reductions in the coefficients of friction of mineral oils by the addition of small quantities of fatty acids to them.

Further experiments have since been made on pistons and piston rings. From the results of the experiments, it appears that the lubrication of piston rings is of the boundary type, and that their frictional resistance will depend on the normal pressure between the rings and the cylinder wall. It is clear, therefore, that any device which will prevent the leakage of the gas or steam from the back of the piston to the space behind the piston rings will improve the mechanical efficiency of the engine. As regards the piston, it may be assumed that in all cases in which there is an appreciable side thrust due to the obliquity of the connecting rod, the frictional resistance of the piston will also be proportional to the load.

In the experiments here described it may be remarked that the friction of the rings is only a small fraction of the total pressure on the piston; thus, at a pressure of 80 lb. per sq. in. the ring friction of a single piston was of the order of 9 lb., which is only 1 per cent of the total pressure on the piston. Assuming the same value of the coefficient of friction for the piston as for the rings, it would appear that in ordinary internal-combustion-engine practice if the lubrication were as efficient as in the experiments, the maximum friction of the piston and rings would be of the order of 3 per cent of the mean pressure on the piston. This is thought to be lower than the value commonly assumed for piston and ring friction, and is probably due to the relatively greater efficiency of the lubrication in the experiments compared with that which exists in practice. (T. E. Stanton, *The Engineer*, vol. 139, no. 3603, Jan. 16, 1925, pp. 70-72, 4 figs., *eA*)

MACHINE PARTS

Gear Drives in Sheet Mills

THE little brother of the main gear drive known as the pinion stand had in the early days spur gears with cast teeth and ran without enclosure or protection. On account of the small number of teeth in these spur pinions hardly more than a pair of teeth were in contact at any time, resulting in a varying angular velocity, tooth shock, and fluctuating surface velocity of the mill rolls. From this, step by step, was developed the modern type consisting of cut double helical teeth with complete oil-tight enclosure. The main gear passed through a similar process of development. The question of lubrication appears to be of the greatest importance as affecting the performance and life of both the main gear and the pinion stands. One type of the fully enclosed housing permits the use of the same oil for the bearings and teeth, and is known as the "single oiling system." For this system of oiling it is necessary to compromise as to the grade of oil, between the demands of the bearings and the teeth, using an oil of as high a viscosity as will flow through the bearings to meet the demand for high viscosity oil on the part of the pinion teeth, where breaking down of the oil film will soon result in tooth wear. In the majority of merchant mills where the pitch velocity is comparatively low an oil of about 600 viscosity gives very satisfactory results on both bearings and teeth.

For the heavy-duty pinion stands where tooth pressures are high, as in blooming mills, plate mills, billet mills, etc. a lubricant of such high viscosity is required for the teeth that it is impossible to use the same for lubricating the bearings. This calls for the "double oiling system" or use of separate lubricants on bearings and on gears. The bearing shells have to be equipped with grooving and wipers as a means of preventing mixing of the two lubricants, as the thinning of the gearing lubricant by the bearing oil soon lowers its viscosity and renders it inadequate for tooth lubrication, while a working of the gear grease into the bearings soon prevents proper circulation of bearing oil, thickens it, and causes the bearings to heat.

Design of the main gears is next discussed as well as the drives. The gear reduction units are classified under two headings, namely, drives transmitting no flywheel power and drives which do transmit flywheel power, the author considering as far as the drive is concerned that the ideal location for the flywheel is in connection with the main shaft and between the mill and the drive. The original arrangement for the high-speed flywheel was a single unit mounted on separate bearings and located between the motor and drive pinion. Another arrangement, first used in 1912, consisted in mounting a cast-steel flywheel on each end of the pinion shaft overhanging the pinion bearings. In this connection the author gives a brief calculation of flywheels and their effects, and an analysis of the conditions of deflection in the pinion shaft.

In the discussion which followed several speakers emphasized the importance of lubrication. The question of wearing out of the gear teeth was also touched upon. (H. H. Talbot, Asst. Chief Engr., United Engineering & Foundry Co., Pittsburgh, Pa., in *Iron and Steel Engineer*, vol. 1, no. 12, Dec., 1924, original paper, pp. 607-612, 15 figs., and discussion pp. 612-615, *g*)

Strength of Wire Ropes

ABSTRACT of the second report of the committee set up by the Institution of Mechanical Engineers several years ago to investigate the strength of wire ropes. (The first report was published in 1920 and aroused such a wide divergence of opinion that it was decided to carry on further experiments.) The purpose of the committee is to establish definite data on which specifications for wire ropes can be based. It would appear that even now the data collected by the committee are not universally accepted as sufficient.

The investigations were confined to ropes not larger than 1 in. in circumference. Eight distinct types of rope were tested in two separate groups, one made from wire 0.021 in. in diameter and the other from 0.036-in. wire. All the ropes had six strands, each of which was built up of from 6 to 12 wires.

These ropes were tested in groups in a machine which comprised a set of pairs of pulleys, or sheaves, in a frame. Each sample of rope was rove around a pair of pulleys, of which the larger one was oscillated so as to give the rope a to-and-fro motion over the smaller test pulley. The tension on the rope was adjusted by means of a long screw and spring, and the number of cycles through which the rope would pass before failure was recorded. The size of the test pulleys was altered from time to time, in order to determine the effect of their diameter on the endurance of the rope.

The preliminary tests were carried out on single wires and a million bends were taken as the limit of endurance, as it was considered to be of a practicable value. It was estimated that a wire of the size being tested, 0.021 in. in diameter, would be stressed to its yield point when bent over a pulley 4.7 in. in diameter. On smaller pulleys the number of bends required to produce fracture was less than 100,000, and on 5-in. and 6-in. pulleys the numbers of bends were of this order when the calculated stress was in the region of the yield stress of the material. Contrary to expectations, it was found that at greater tensions an increased number of bends

was necessary to produce fracture. Possibly the added tension, beyond that which caused yield, produced a more favorable stress range which would account for this apparent anomaly. On pulleys of 7.5 in. and 10 in. diameter the wire showed great endurance, the number of bends before failing being over a million, and in these cases also the tension produced no marked effect, although so high that yield must have been produced.

When the experiments were extended to include stranded wires, the peculiarity just referred to did not reappear, and in each case the tension carried by a strand for a given number of bends was greater on a large pulley than was the case with one of smaller diameter, while the number of bends required to produce fracture on a given pulley increased as the tension was diminished.

After the separate strands had been tested the completed cables were put on the machines and were tested at tension stresses which were calculated by dividing the total tension in the rope by the cross-sectional areas of the wires forming it, and the bending stress from the formula Ed/D, where E = Young's modulus, d = diameter of the wire, and D = diameter of the pulley.

On comparing the results of the performances of the cables built up of 0.021-in. wires with those of 0.036-in. wires, which represents an increase of approximately three times in the sectional area of each wire, it is observable that on the 14-in. pulleys the large wire cables were superior to small wire cables under long-endurance conditions, while on pulleys having a diameter suitable for the wire diameter, they were immensely so. The large wire cables failed rather badly on 10-in. pulleys, thus giving an indication that the critical diameter for cables of 0.036-in. wire is in the region of 14 in.

One of the most remarkable results of these tests, which is quite contrary to the remarks made in the previous report of the Committee, is that there may be occasions when the lubrication of a rope will actually reduce its endurance.

The results obtained are very completely set forth in the original report. From this it would appear that among other things single wires tested by repeated bending over pulleys gave unexpected results, standing more bends under greater tension. The bearing pressure between the wire and pulley appears to be important in the case of strands. Lubrication generally reduces the life of a rope. With an ordinary-lay rope the pulley design is not very marked. A hemp core to a strand proved of advantage particularly when associated with Lang's lay, but the latter lay showed no advantage with a 19-wire strand. A soft-core wire in the 7-wire strand proved a disadvantage on a large pulley.

The useful life left in a rope cannot yet be predicted in general terms from a record of wire breakages. If the working conditions be specified, it might be possible.

The work done in moving a cable round a pulley bears no relation to the endurance.

The occurrence of brittle-wire fractures in all test specimens showed that bending fatigue was an important factor in the failure of all ropes over pulleys.

Wires fractured most frequently at contact with the pulley or where adjustment strands touched. Only on very large pulleys, which permitted a rope to carry a high tension for a considerable number of bends, were the wires so worn that the reduction of their sectional areas appeared materially to assist fracture. (*The Engineer*, vol. 138, no. 3600, Dec. 26, 1924, pp. 719–721, *eA*)

MACHINE SHOP

Machining Large Turbine Speed-Reduction Gears

In an article in Mechanical Engineering describing the Construction of the Repair Ship *Dobbin* at the Philadelphia Navy Yard (vol. 46, no. 4, April, 1924, pp. 173–178) mention was made of the enormous speed-reduction gears used on this ship and the difficulty encountered in cutting them. The present article gives details as to the problems which occurred in this work and were successfully solved. To give an idea of the size of the job, it is enough to say that the pitch-circle diameter of the big gear was over 146 in. and the width of face 21 in.; the weight of the gear wheel was 60,000 lb. and it was run at 105 revolutions and driven by a pinion weighing 1500 lb. and running at 1550 revolutions.

The machines for cutting the teeth in the gear wheel and pinions were equipped with what is known as a "creeping gear" developed by Sir Charles A. Parsons. The principle of the creeping gear is described as follows by Parsons in his paper "Mechanical Gearing for the Propulsion of Ships," presented before the Institution of Naval Architects on March 13, 1913:

> In the process ordinarily adopted, in which the work is mounted on a table rotated by means of a worm and worm wheel, the latter being attached permanently to the table, the errors will be some function of the angular position of the work, and, therefore, lie in planes through the axis of rotation; and if, as is mostly the case the errors of the parent gear are periodic, these planes will lie at equal angular intervals and will come into mesh periodically. Now, it will be seen that, if the work is given a small steady advance in relation to the table, the errors instead of lying in planes through the axis, will lie in spirals around the wheel, and that when put to work they will be obliterated and leave a true wheel.

The "creeping gear" supplies the means for imparting a small movement of the work relative to the master worm wheel.

One of the problems which had to be solved was the checking and adjustments of the machines which had been built on the other side in war time and shipped across the Atlantic. In fact, some of the features had to be changed, as for example, heavier bearings installed, as the gears to be cut were larger than those for which the machine was originally designed. It has been already mentioned in the article referred to above that an effort was made by employment of electric motors operated from a bank of storage batteries to maintain constant temperature conditions during cutting operations. As a slight difference of temperature on account of the enormous size of the gear might produce appreciable irregularity in the form of the teeth, the test gear blank was tried on the machine before the cutting of the actual piece was admitted and experience from this indicated that it was desirable to maintain the cut constant after it has been started, particularly the finishing cut, due to the fact that there are certain strains in the machine which remain constant only as long as the cutting is continued.

Extreme attention was paid to the accuracy of the gear-cutting operation and special methods developed for this purpose are described in the original article. (Lewis H. Kenney, Engineer, U. S. Navy Yard, Philadelphia, Mem. A.S.M.E., in *The Iron Age*, vol. 115, no. 4, Jan. 22, 1925, pp. 263–268, 7 figs., *d*)

Planing Steel Plates for Pipe Making

Steel plate designed for lock-bar-pipe making has to have its edges planed and upset. To do this a special machine was designed and recently installed at the plant of the Riter-Conley Co., at Leetsdale, Pa.

It consists essentially of two main beds 45 ft. in length carrying the lead screws and carriages. Each side of these beds is formed into a beam on which the plates rest. Above these beams are supported two heavy clamping beams 32 ft. in length, which by means of hydraulic pressure of approximately 100,000 lb. at the ends of the beams, securely clamp the plates for the full length of the two edges that are to be planed and upset. In turn these clamping beams are supported by two overhead heavy cross-beams resting on columns. The two lead screws are 6 in. in diameter, have triple threads, and are connected by bevel gears to a common drive shaft which a 200-hp. motor drives through a reduction-gear unit.

Each carriage is provided with a tool holder carrying six cutting tools and a holder for eight vertical upsetting rolls. In front of the carriage is placed a push-out bar by means of which the finished plate is pushed out of the machine, and in the back of the carriage is placed a clamping device by the use of which the unfinished plates are gripped and moved into the machine. Plates vary in width from 30 in. to 12 ft., this necessitating that the main beds and clamping girders be adjusted to this extent. For this purpose the main beds are placed on five shoe plates provided with T-slots on which they can slide and be bolted to after adjustment is made. The clamping beams have similar adjustment, but are supported and slide on the lower flange of the overhead cross-beams.

As the two edges of the plates used in lock-bar pipe are not parallel due to the fact that one end of the finished pipe section must be of smaller diameter than the other so that one section of pipe can fit into the other, the main beds and clamp girders must have individual adjustment at both ends. For this purpose the

shaft driving the cross-screws is provided with two jaw clutches, each of which can be thrown in and operated individually, or both together.

The machine has to be very rugged as it was found that to upset the edge of a half-inch plate a pressure of approximately 400,000 lb. was required. There is also a considerable stress from the cutting tools, as the six cutting tools sometimes have to remove as much as 2 in. of stock from each of the two edges. (*Iron Trade Review*, vol. 76, no. 3, Jan. 15, 1925, p. 229, 1 fig., *d*)

MACHINE TOOLS

Bullard Four-Spindle Mult-Au-Matic

A NEW tool designed along the same lines as the six-spindle Mult-Au-Matic but intended for use where production schedules do not require the maximum quantities of which this latter machine is capable, and where the work in many instances does not require any very great variety of machining operations on any one piece. Moreover, the four-spindle machine is naturally less costly than the bigger unit.

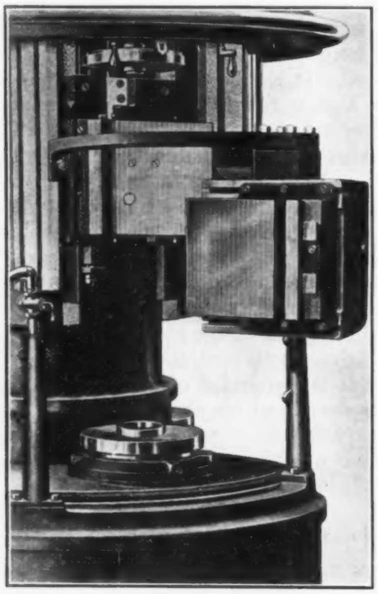


FIG. 4 FOUR-SPINDLE BULLARD MULT-AU-MATIC

The machine comprises four individual production units under automatic centralized control with four work-holding spindles mounted on the carrier and four stations provided about the central column for processing the work. The first station without tools permits the operator to unload the finished work and chuck the rough piece while the spindle stands quiet. Stations 2, 3, and 4 are provided with universal tool-carrying heads which may be set independently in rate of speed and in direction, amount, and rate of feed within ample limits to suit the requirements of the work to be performed at each station.

A typical working station showing universal main head and supplementary side head is shown in Fig. 4. The supplementary side head is mounted where sufficient tooling capacity for certain work is not available with the use of the three universal main heads, and it may be applied at any or all of the three working stations. This side-head unit is mounted on a bearing provided on the central column and is braced by an arm which extends across the column face. At those stations where the supplementary side head is attached only vertical feed may be used for the main head.

The cycle of operating functions begins with the indexing of the carrier and a presentation of new work at each station. All tool heads rapidly advance to the point of cutting at a rate which is constant at all times and bears no relation to the feed. At a predetermined point rapid traverse is stopped and the feed motion is engaged, proceeding through the cuts at the respective rates set independently at each station. Upon completion of the work, the tools and heads are retired under rapid traverse through the same paths by which they have advanced. As the last head to complete its work returns, the indexing mechanism is automatically tripped and the cycle is repeated. (*Bullard Machine Tool Co.*, Bridgeport, Conn., factory catalog, 4 pp., illustrated, *d*)

MARINE ENGINEERING

V-1—America's Biggest Submarine

DESCRIPTION of a new submarine of the cruiser type recently commissioned. It is of a surface displacement of 2164 tons with a surface speed of 21 knots and submerged speed of 9 knots, powered by 6500 shaft hp. and equipped with six 21-in. torpedo tubes, one 5-in. 51-caliber rifle, and two Lewis machine guns. Judging by recent statements in the general press it is inferior both in size and in armament to the X-1 British submarine, likewise commissioned quite recently (after material changes in a previous design).

The vessel is propelled by four Diesel engines, two of which are connected directly to the propeller shafts by friction clutches and the two others connected indirectly by an arrangement of electric drive similar to that now standard for all capital ships of the U. S. Navy. [The principal features of this drive were described by W. L. R. Emmet in his paper on the collier *Jupiter*, Journal of The American Society of Mechanical Engineers, vol. 34, March, 1912, pp. 373–378.] By this means either pair of engines may be used alone to drive the vessel at slow or moderate speeds, and both pairs may be used when high speeds are required. The forward or electric-drive engines are of the Bureau of Engineering four-cycle type manufactured by the Government at the New York Navy Yard, and based on the M.A.N. design. The other engines are of the Sulzer two-cycle type and built by the Busch-Sulzer Bros. Diesel Engine Co., of St. Louis, Mo.

Among the features of the engine plant is an arrangement by which water is distilled by the utilization of heat of the exhaust gases. (*Motorship*, vol. 10, no. 1, Jan. 1925, pp. 17–18, illustrated, *d*)

Oil Fuel for Motorships of Tomorrow

DISCUSSION of the question of available fuel supplies for motorships. Among other things the author points out that while until recently, except in the Orient, practically nothing but what is known as gas oil was used in Diesel engines, in the Orient another fuel oil was supplied and proved satisfactory. He gives interesting statistics issued by Lloyd's Register showing the increase in tonnage of oil-driven vessels, from which it would appear that in 1914 there were 1,310,209 gross tons of oil-fired steamers and 234,287 gross tons of motorships. These grew by the end of the war to 5,326,678 and 955,810 gross tons, respectively, and rose in 1924 to 17,154,072 gross tons for oil-fired steamers and 1,975,798 gross tons for motorships.

The author gives a list of bunkering stations having a supply of Diesel oil, and covering practically the seven seas. His feeling is that at least at present there is rather overproduction of oil than lack of ability to supply the demand, and he does not look for any shortage of it or exceedingly high prices for quite sometime to come. (J. J. McPhie, Manager, Fuel Oil Department, Asiatic Petroleum Co., in *Motorship*, vol. 10, no. 1, Jan., 1925, pp. 24–25, *g*)

MECHANICS (See also Lubrication: Friction of Pistons and Piston Rings)

The Torsion Problem of Curved Beams

GIVEN a beam in elastic equilibrium whose mean fiber is a continuous curve and which is acted upon by couples of arbitrarily directed axes, the problem which the authors set is to determine:

1 The system of forces acting on any section normal to the mean fiber, and

2 The stresses existing in this section and the limiting of those stresses.

The problem is solved mathematically and the authors find a solution of the problem of the stresses in plane and skew beams acted upon by couples for all cases where separate solutions exist for the problem of torsion of the straight beams and of flexion of the plane curved beams. This is postulated on the validity of the principle of superposition of forces and their effects. The solution obtained is applied then to bars of circular, elliptical, and rectangular cross-section, and it is found that if the applied forces are not pure couples they can in each section be reduced to a couple and a force. This force will in general cause in the further sections an additional bending around the y- and z-axes which is to be added to the values of the moment vectors M_y and M_z, wherein y and z are referred to as the principal axes of symmetry of the cross-section in question. The method described can also be used for non-prismatic beams provided the variations of profile are sufficiently slow to make the

disturbance caused thereby on the stress distribution negligible. (Paul A. Heymans, Mass. Inst. of Technology, Mem. A.S.M.E., and W. J. Heymans, University of Ghent, Belgium. *Journal of Mathematics and Physics, Mass. Inst. of Technology*, vol. 4, no. 1, Jan., 1925, pp. 33–57, 15 figs., *m*)

New Method for Computing the Bursting Forces Acting on Walls of Vessels and Pipes

AFTER comparing various formulas the author comes to the conclusion that in regard to Barlow's formula, engineering practice has shown that it gives in all cases unacceptably small dimensions for cylinder walls and that the results of the Lamé formula are more suitable for materials with high tensile resistance (10,000–20,000 lb. per sq. in.) and of the low pressure P. With materials of low resistance and considerable pressure P, this formula gives impossible results and none of the corrections of coefficients make it applicable when the allowable stress S is small and P is high.

It must be noted that the majority of cases where the strength of a cylinder or of pipe walls is to be figured and the coefficient of the safety determined precisely, are the cases where P is nearly equal to or somewhat larger than S, i.e., where Lamé's formula is claimed to be wrong. These cases are centrifugal pumps, condensers, steam turbines, accumulators, intensifiers, cast-iron pipes, special cast-iron and cast-steel vessels, etc. In other words, all cases where proper dimensions have not been standardized by long and troublesome experience, like for instance, steam boilers and piping, cylinders for steam engines, etc.

The author's own formula is based on Pascal's law, according to which internal pressure acting normally to the inside walls of a cylinder will have a tendency to produce deformations of two different characters: first, radial expansion of cylinder, and second, deformation of cylinder of an "envelope" character, which is due to the excessive extension of the wall at its weakest point.

A further deduction will be that the axis of envelope is the diameter through the weakest point of the cylinder's circle, and the point diametrically opposite to the weakest point will be the neutral point of the envelope. Referring to Fig. 5, a* is the weakest point, xx the envelope, c the neutral point of the envelope, and ca the axis of the envelope.

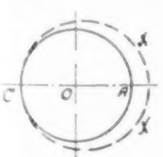


FIG. 5. DEFORMATION OF CYLINDER UNDER INTERNAL PRESSURE

It must be pointed out that the two deformations of the cylinder, namely, radial and envelope expansion, have different values for different materials. Materials with high limits of elasticity, like bronze and steel, have considerable envelope deformation before rupture occurs, and materials with low limits of elasticity, like cast iron, have very small envelope deformation—it practically occurs at the very moment of rupture.

From this the author derives the following formula for the tension force at point a due to a horizontal component which is

$$\delta'' = pr \qquad [1]$$

The total tension on point a will be:

$$\delta = \delta' + \delta'' = 2pr \qquad [2]$$

where δ' is being produced by the vertical component of the Pascal force, and δ'' by the horizontal component of the said force.

Formula [1] gives the value of the tension force which produces rupture of cylinder walls about 100 per cent higher than Barlow's formula, but the author believes that the Barlow formula is applicable not to a vessel of a hollow cylindrical shape, but either to a solid circular bar with a very narrow longitudinal passage in the middle of the section, or to a flat vessel with walls reinforced by ribs to resist the bending of the walls due to internal pressure. He proceeds next to the development of formulas for vessels other than circular.

* Lower-case a is used throughout in the text, but A in the figure.—EDITOR.

The question how an error as high as 100 per cent escaped the attention of engineers is answered by the author by presuming that in cases where a coefficient of safety equal to four was expected there was only one equal to two, with the result that any unexpected defect in material or workmanship or overload caused destruction of the pipe—and this is supported in his estimation by a large number of explosions of pipes, tanks, etc. (I. M. Prokofieff in Paper No. 195 read before the Brooklyn Engineers' Club, April 10, 1924. *Proceedings of the Brooklyn Engineers' Club*, vol. 22, no. 4, July, 1924, pp. 34–49, 14 figs., *t*)

MOTOR-CAR ENGINEERING

Six-Wheeled Tractors

AN ARTICLE describing a Belgian design together with an editorial discussing the whole subject of six-wheelers. On the Continent the type preferred is a four-wheeled tractor pulling a two-wheeled trailer. In England the six-wheeler built as an indivisible unit is preferred.

According to the editorial, superficially, it would seem that the detachable-trailer system has everything in its favor through being more flexible and permitting use of the tractor while the trailer or trailers are being loaded and unloaded. Examined more closely, another view appears. For equal strength and capacity a six-wheeler can be built with a lower chassis weight than a tractor and trailer, and furthermore it is probable that the design can be so arranged that there is a greater proportion of the total weight used as adhesion load on the driving wheels.

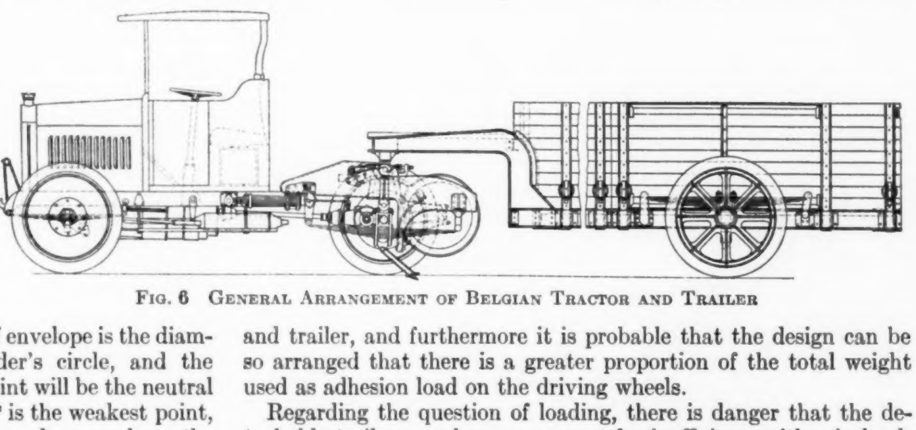


FIG. 6 GENERAL ARRANGEMENT OF BELGIAN TRACTOR AND TRAILER

Regarding the question of loading, there is danger that the detachable trailer may become a cover for inefficiency either in loading method or equipment. An important factor in the decision as to the selection of type is the average distance of transport, as the longer the distance the less will be the percentage of possible saving on the tractor runs. The unit under consideration is built by the Société Anonyme Auto-Traction of Antwerp. The general arrangement of the tractor and trailer is shown in Fig. 6. It has a four-cylinder engine of the Knight sleeve-valve type, delivering 39 hp. at 1500 r.p.m. The clutch is of rather interesting design and is, among other things, provided with a special lubricator for the thrust bearing, oil being conveyed through a piece of flexible metal pipe from a conveniently placed cup. (*The Automobile Engineer*, vol. 15, no. 198, Jan., 1925, editorial on p. 1 and article on pp. 2–8, illustrated, *gd*)

Pneumatic Brakes

DESCRIPTION of a device made in England by the Reynolds Tube Co., Ltd., Birmingham, intended primarily for the operation of four-wheel brakes. The device consists of a single-cylinder air compressor driven direct from the engine and feeding air through a special form of valve into a steel cylinder forming a storage tank and provided with a safety valve. From the storage tank a pipe runs to a valve regulator connected up to the usual brake pedal. The compressor runs whenever the engine does.

For operating the rear brakes the cylinder containing the piston and piston rod is mounted on the outside of the torque tube. The piston is held in its zero position by a coiled spring, but when air pressure is admitted to the cylinder the piston is forced outward. The piston rod carries on its extremity a pulley wheel embraced by a steel cable, each end of the latter is connected to a brake on either side of the car.

In tests made it was found that to pull a car up to a dead stop

from 40 m.p.h. on level it took 10 sec. with the pneumatic brake and 14 sec. with the side brake, but the test cannot be regarded as very conclusive as apparently neither of the two sets of brakes was in good working order. (*The Autocar*, vol. 53, no. 1523, Dec. 26, 1924, pp. 1265–1266, 4 figs., *d*)

PHYSICS

Skin Friction

Skin friction is a technical term used to cover actions which occur in a viscous fluid in the immediate neighborhood of a solid body in motion relative to the fluid. In the common usage of the expression it does not include the resistance due to eddies but only the tangential forces arising from the shearing of the viscous fluid over those parts which are held by the solid boundary. In many cases—roughly those associated with what are called streamline bodies—the layer in which the forces due to shearing are important is very thin and is appropriately called a "skin." Alternatively the expression "boundary layer" is used. In the circulation theory of aerofoils developed by Prandtl and his school from previous work by Lanchester, the conception of an aerofoil is modified so as to include the skin. The effects of the boundary layer are all-important in determining the forces on an aerofoil and the flow outside it, but the results of recent experiments at the National Physical Laboratory give considerable support to the hypothesis that the net effect is a circulation of the fluid as defined by well-known expressions independent of viscosity. This is true even while it is impossible as yet to estimate with accuracy from mathematical hypotheses the amount of the circulation.

Sometimes the whole fluid constitutes the skin; examples occur in the experiments of Hele-Shaw and in the theory of the lubrication of journals; in general these cases can be solved mathematically. Taking account of all methods available, analytical, graphical and mechanical, it may be said that we are satisfactorily equipped for dealing with specific motions limited in this way. Application by Michell to thrust bearings in marine-engineering practice has shown how important a correct theory may be. By processes in existence up to a few years ago, thrust bearings had been developed to carry a maximum thrust per square inch of about 80 lb. Higher pressures than this led to failure of the lubrication and the seizing of the bearing. Applying a theory of skin friction, Michell revolutionized the design of thrust blocks and pressures of 3000 lb. per sq. in. can now be reached. The saving in size and cost is appreciable.

Stanton in a recent paper before the Royal Society stated that a preliminary investigation indicated that it was essential for the maintenance of the film that there should be a difference between the radius of the bearing and that of the journal, the two surfaces being eccentric to an extent depending on the load, speed, and lubricant. The theory is deduced from the general equations of motion of an incompressible fluid in two dimensions expressed by a system of partial differentials, with certain restrictions when dealing with the skin or film only. Equations embodying these restrictions have been given by Stokes for the very slow motion of viscous fluid when not confined to films. Skin-friction phenomena find an application in the case of an airplane wing supporting a load, but the essential difference between the aeronautical problem and that of lubrication arises from the absence of the second solid surface represented by the bearing. A flat plate moving in its own plane through the air carries fluid with it, but there is no obvious limit to the thickness of fluid affected by the motion. With some experimental justification it may be assumed to be small. Prandtl retains all the terms of the steady motion and considers the consequences of assuming the existence of skin. This hypothesis leads to the result that velocities across the skin are small compared with those along it, and an attempt is made to give some measure of mathematical precision to this physical idea. Fundamental equations for the boundary-layer theory are derived and it is shown that the theory of lubrication is a special case of them in which certain terms are ignored.

Experiments apparently justify the general applicability of the equations derived to the case of an aerofoil, with certain reservations as to its validity in the wake. They also show that the boundary layer is very thin, in fact so thin as to be beyond the reach of the instruments used. (Stanton ran into the same difficulties in attempting to examine the boundary layer in a pipe.) An attempt to solve some of the equations found on the boundary-layer theory, taking the pressure from experiments at the National Physical Laboratory, is being made at the Imperial College of Science and Technology and is meeting with a gratifying measure of success. The skin friction over the leading portion of the upper surface has already been calculated and it appears that the thickness of the boundary layer there varies from $^1/_{1000}$ to $^3/_{1000}$ of the chord.

Using some of the work of Blasius (at one time a student of Prandtl), who gave solutions of some of the equations for a flat plate, the author proceeds to a further mathematical investigation of the subject and obtains among other things the force due to skin friction and the drag coefficient, and finds that the latter is a function of Reynold's number ($\bar{q}b/v$) and decreases as the viscosity decreases. Had the skin friction been proportional to the square of the speed, the drag coefficient would have been constant.

The author considers next how the theory compares with the experiment and finds that they do not compare very well. He explains this, however, by assuming that the texture of the skin of an aerofoil is greatly different from that of a flat plate and that no deduction can safely be made from one to the other. The article is accompanied by an extensive discussion. (Prof. L. Bairstow in *Journal of the Royal Aeronautical Society*, vol. 29, no. 169, Jan., 1925, original paper, pp. 3–14, 4 figs., and discussion, pp. 14–23, *te*)

POWER-PLANT ENGINEERING (See also Fuels and Firing: Automatic Kiln Stoker; and Pumps: Steam-Jet Condensing-Type Vacuum Pump)

Electric Power as a By-Product of Process-Steam Generation

One of the conclusions to which the author comes is that where there is a large distribution of steam with relatively long transmission distances such as caused by a separate boiler unit, it might be cheaper to build a high-pressure steam plant with high-pressure distributing mains rather than a low-pressure plant, even though the steam requirements are quite low in pressure. If steam is generated at high pressure and required only at low pressure and temperature, either engines or turbines may be substituted for reducing valves, so as to extract the work from the steam to generate power or electrical energy and use the low-pressure exhaust steam for the heating or process purpose.

In general, the following methods are considered for making power as a by-product: (1), High-pressure engines or turbines exhausting to process mains; (2) bleeder or extraction turbines; (3) low- or mixed-pressure turbines using process exhaust. A description of each type is given and its relative advantages considered.

According to the author, with low-pressure turbines taking waste exhaust steam, the ultimate cost of power is about 1.63 cents per kw-hr. as compared with 1.62 cents per kw-hr. at which steam can be bought from central stations. In itself, therefore, it would not pay to tie up the necessary additional capital and take the trouble to make power, but if a suitable process load is available, and all the steam from the engine is absorbed in heat and process, power could be generated at a total cost per kilowatt-hour of 0.9 cent, which would make it worth while.

The author discusses next the use of high-back-pressure turbines for processes to produce a portion of the power and believes that this would give, under proper conditions, a very material saving. Low- or mixed-pressure turbines are very attractive propositions where they can be used. The requirements are a supply of exhaust steam and a plentiful supply of cold condensing water. These turbines are, of course, very sensitive to vacuum conditions, since their entire working range is about 15 lb. when operating low-pressure. Therefore a 29-in. vacuum in winter and not less than $27^1/_2$ in. in summer is essential. While operating low-pressure the only additional fuel requirement is that necessary for operating the condenser pumps, or about 1 per cent of the steam equivalent for a high-pressure turbine carrying the same load. These pumps, of course, exhaust into the turbine. By conserving all the exhaust heat possible the admission of high-pressure steam to carry

the load can be reduced to a minimum, and the cost of generation reduced to practically the investment charges and maintenance.

At the same time the author calls attention to the fact that often the problem of manufacturing by-product power is unattractive due to the design of the process-heating units. Thus, often quite high pressures must be carried, so that a non-condensing turbine exhausting at these pressures becomes uneconomical. (Theo. Maynz, Cons. Engr., Cleveland, Ohio, Mem. A.S.M.E., in *Chemical and Metallurgical Engineering*, vol. 32, no. 1, Jan. 5, 1925, pp. 5–9, 6 figs., *p*)

PUMPS

Steam-Jet Condensing-Type Vacuum Pump

THE steam-jet type of vacuum pump has reached a high state of development due to increased general attention paid to the condenser and condenser auxiliaries, especially in turbine plants. In the older types of ejectors the second stage is required to handle the air and also the motive steam from the first stage, and because of this the second stage must be designed with a high ratio of compression. This is not an advantage, and a new type shown in the original article was designed so that the motive steam used in the first stage is removed after having completed the initial compression of the air. This relieves the second stage of this extra duty during completion of the compression cycle, thus making possible the use of a lower ratio of compression.

Steam at a predetermined pressure is supplied to the steam nozzles, through which it passes and expands to the desired vacuum, also predetermined. The high velocity of the steam attained during expansion, and not its kinetic energy, is utilized to entrain the air by friction from the apparatus being served. The mixture of air and steam is conveyed to the diffuser, in which it is compressed gradually to the pressure obtaining within the intermediate condenser.

Steam at the same inlet pressure is supplied to the second-stage nozzle, through which it passes and expands to a vacuum slightly in excess of that prevailing in the intermediate condenser. Since the first-stage steam has previously been condensed in, and subsequently removed from, the intermediate condenser, the second-stage ejector has only to remove air, and in addition that quantity of water vapor equivalent to saturation at the temperature and pressure prevailing at the vapor outlet of the intermediate condenser. This mixture of water vapor and air is extrained by the high-velocity steam jet into the second-stage diffuser, where it is compressed gradually to atmospheric pressure. The exhaust may or may not be led into an after condenser, it being essential in either event to maintain the back pressure at a minimum.

The intermediate condenser is cooled by main-unit condensate or outside water, so as to condense the steam and also further to cool the air and non-condensable vapors before admission to the second stage.

It is claimed that the steam consumption of the condensing-type air ejector is materially less than that of the non-condensing type, because the steam used in the first-stage ejector is condensed in the intermediate condenser and immediately removed therefrom; also, the extrained air is simultaneously liberated and reduced in volume and temperature. Thus the decrease in specific volume of the air, and the separation of moisture therefrom, greatly reduces the steam required by the second-stage ejector to withdraw the air from the intermediate condenser and exhaust it to a region of atmospheric pressure. Application of the condensing-type air ejector is therefore justified by its apparent low economy ratio or "pounds of steam condensed per pound of air removed."

The question of economy in the operation of a condenser is discussed with reference to the various types. Also the proper selection of operating steam pressure. Curves are given showing the performance of a condensing-type air ejector and the effect of cooling-water temperature on ejector capacity is discussed. In this respect the author comes to the conclusion that any reduction of the partial pressure and temperature of the vapor will correspondingly reduce the vapor content of the mixture. The result is an increase in the air content of a given weight of the mixture to be removed by the air ejector.

The effect of variable cooling-water temperatures is indicated by Fig. 7; thus evidencing the importance of circulating cold raw water through a portion of the intermediate condenser in order to obtain maximum ejector capacity, consistent with water temperature, for all conditions of main-unit load vacuum and condensate temperature. It is obvious, therefore, that the capacity lines indicated in Fig. 7 will vary but seldom, and then only with seasonal

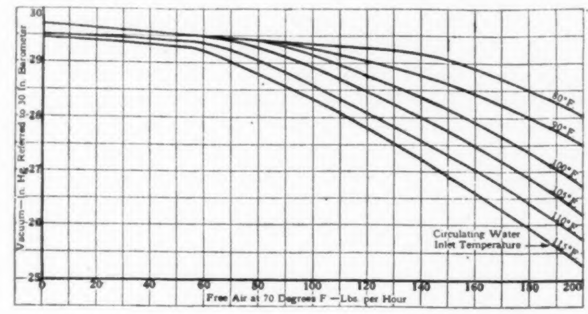


FIG. 7 TYPICAL CURVES SHOWING EFFECT OF COOLING-WATER TEMPERATURE ON EJECTOR CAPACITY

changes of the main-injection-water temperature. (J. H. Smith, Condenser Engr., Westinghouse Elec. & Mfg. Co., in *The Electric Journal*, vol. 22, no. 1, Jan., 1925, pp. 17–23, 11 figs., *ceg*)

RAILROAD ENGINEERING

Delaware & Hudson High-Pressure Locomotive

THIS locomotive is operating between Oneonta, N. Y. and Mechanicsville, a distance of about 87 miles, where there are grades 0.8 per cent and 0.77 per cent one way, and 1.45 per cent and 1.42 per cent the other way for about 10 per cent of the distance. It has made between 7500 and 8000 miles with tonnage trains and is still being operated under a brake-in speed-limit order of 25 m.p.h., which gives a piston speed between 700 and 750 ft. per min. At this speed, which is unfavorable from an operating standpoint, a combination of a moderate degree of superheat and multiple expansion has proved more economical than a combination of relatively high speed and single expansion in any consolidation-type locomotive performing similar service at speed limits of from 35 to 45 m.p.h.

It is stated that with its speed limited to 25 m.p.h. the new locomotive makes the trip over the division in less time than the other superheated single-expansion-type locomotives which operate at from 35 to 45 m.p.h.

As regards maintenance, no leaks developed in the boiler. (Some trouble was experienced at the outset in making the joints of the outside firebox covering, but this had been corrected.) The locomotive is equipped with a desaturator, but there is some question as to whether this is necessary.

There has been no valve- or cylinder-packing, bushing, piston-head, or piston-rod-packing trouble, and no more attention is required in this regard than with the ordinary single-expansion-type locomotives operating under 200 lb. pressure. Waste of steam at the pop valves has given some concern, both when working steam and when drifting. This is now controlled through the regulating of ashpan dampers. Considerable trouble has been experienced with the reflex-type water-gage glasses breaking, probably due to extreme temperature changes. As this has not been experienced in stationary boiler service where higher pressures and temperatures are used, it is expected that a new design the manufacturers are now developing will overcome this difficulty.

The application of an interbearing driving-box brass to the main boxes, similar to that used on three-cylinder locomotives has substantially overcome a tendency to develop the pound in these journals which was evident in the early operation of the locomotive. The engine tends to run to the left, toward the low-pressure cylinder, cutting the leading-truck wheel tire. The cause for this has not yet been determined. The distribution of power between the high- and low-pressure cylinders is satisfactory, except at speeds between 12 and 18 m.p.h.; intercepting-valve and valve-motion changes will probably correct this. With eight tons of coal the

Horatio Allen can move the same tonnage between Oneonta and Mechanicsville northbound as two smaller superheated single-expansion consolidation locomotives using 12 tons of coal, the fuel used ranging from straight run-of-mine bituminous to a mixture of 60 per cent bituminous and 40 per cent buck anthracite.

With respect to the care of the boiler, it is stated that on November 2, 1924, the boiler was washed out in the enginehouse, the total time required to complete the job being 12 hr. An inspection at that time showed that the top drums, longitudinal and vertical water tubes, and arch tubes were clean, while the bottom drums and boiler shell had a slight accumulation of mud. The disposition of the sediment as found at wash-out periods is evidence that the water circulation is very active, particularly through the vertical water tubes between the lower and upper drums. (John E. Muhlfeld, Mem. A.S.M.E., at a meeting of the New York Railroad Club, Jan. 16, 1925; abstracted through *Railway Age*, vol. 78, no. 4, Jan. 24, 1925, pp. 279–280, *d*)

Diesel Electric Locomotive Built for Russia

THE locomotive is intended for freight service and has five pairs of drivers. One motor is used for each driving axle, making five in all. There are two pinions to each motor armature shaft, one on each end, but only a single gear ratio since the double pinion and gears are in reality only the separate halves of herringbone gears. The teeth appear to have about a 45-deg. helical angle and the axle thrusts balance each other. The gear ratio is 1 to 6.4, and the rating of each motor is 130 kw.

Current is furnished to the motors from the main generator driven by the main engine through a flexible coupling. Separate excitation is provided and the current for it is drawn from the main exciter geared to the main engine in a two-to-one ratio. A small generator driven from the engine shaft by a belt provides separate excitation for the main exciter. The whole gives a compound Ward-Leonard system in which only the secondary exciter current need be varied and only five amperes have to be handled in the locomotive controller. The source of power for the locomotive is a M.A.N. Diesel engine modified in the light of the experience of the service of these engines on submarines. It is of the four-stroke cycle type, six cylinders, 17.71 in. by 16.53 in., and is rated at 1200 b.hp. at 450 revolutions.

Steel castings of thin section are extensively used in the design of this engine and the cylinder jackets are bolted together from top to bottom in such a manner as to make a deep integral box structure of the entire engine. Since the bedplate which is employed (also of cast steel) has an exaggerated depth with the main bearings located down inside of deep notches, a box frame in the ordinary sense of the word is dispensed with. The cylinders and jackets are, in fact, mounted directly on the bedplate. Machined flanges running up and down the jackets over their entire height make it possible to bolt them together as a rigid whole in the manner referred to in the preceding general description.

Data of the performance of the locomotive and curves of performance under normal and overload conditions are given. Among other things, the Diesel engine attained 1500 i.hp. during a 100-min. peak-load run. (*Oil Engine Power*, vol. 2, no. 12, Dec., 1924, pp. 633–637, 6 figs., *d*)

REFRIGERATION (See Engineering Materials: Cellular India Rubber Insulation; and Thermodynamics: Heat Transmission of Insulating Materials)

RESEARCH

Research Method for Blast Furnaces

DESCRIPTION of a symbolic method for designating conditions observed in the operation of a blast furnace. The method is applicable with proper variations to other problems.

One of the difficulties in conducting research investigations on the blast furnace is the great number of variables which have to be observed and recorded. Furthermore, practical experience is necessary to interpret intelligently the results of the various operations as they appear from day to day in blast-furnace work. With this in view a system was invented which might serve, first, to record the facts of blast-furnace operation, and second, to arrange these facts in a quick, orderly way so that they could be easily read and understood.

As it is difficult to write things down, a set of symbols was devised to tell the story. About 100 symbols are now used. These symbols were developed in a logical manner and in such a way that the smallest degree of difference could be recorded. For example, the top of the slag sample was carefully observed and it was decided that the piece with an arched top would be represented by ⌒ (an arch). If the sample top were flat, or level, it would then be represented by — (a straight line), or if sagged it would be represented by ⌣ (a concave line). It is readily seen now that all kinds of slag tops can be designated simply by varying the degree of curvature of the line convexly or concavely to the degree that is found in the actual slag sample.

The symbols are in reality a shorthand system for noting blast-furnace conditions. A sample of this is given in Fig. 8. The original article gives two samples of records, together with a more or less complete explanation. (Wallace G. Imhoff and Donald E. Ackerman in *The Iron Age*, vol. 115, no. 3, Jan. 15, 1925, pp. 203–211, illustrated, *dp*)

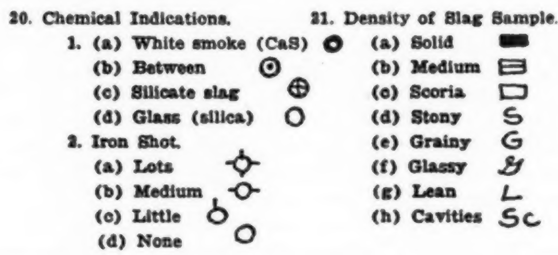


FIG. 8 SAMPLE OF SYMBOLS FOR DESIGNATING CONDITIONS OF BLAST-FURNACE OPERATION

SPECIAL PROCESSES (See Machine Shop: Planing Steel Plates for Pipe Making)

SPECIAL MACHINERY

A Gyro Compass Incorporating Two Gyroscopes

IN a gyro compass two gyroscopes are used for the purpose of eliminating the deviation of the compass introduced by the oscillations of the ship due to wave motion. In the Sperry compass one of the gyroscopes is meridian seeking and the other the reverse; it is claimed, however, that the latter is compelled to follow the former by discontinuous torques. In the Henderson compass both gyroscopes are meridian seeking, all torques being continuous functions of the interaction of the two gyroscopes providing mutual damping. The mathematical analysis of the motion of this latter compass, the conditions for its stability, and the investigation of the damping coefficients of both periods are discussed.

Among other things, it is shown how the two periods of oscillation of a structure carrying two gyroscopes, such as a gyro compass, may be calculated; likewise the conditions for their mutual damping and the various elements of design are established. It is also shown under what conditions the compass settles on the meridian with both rotor axes horizontal. (Prof. Sir James B. Henderson in the *London, Edinburgh and Dublin Philosophical Magazine*, vol. 49, no. 289, Jan., 1925, pp. 273–283, 4 figs., *m*)

TESTING AND MEASUREMENTS

The Measurement of Pressure

AN EXTENSIVE paper written as part of the author's work in connection with the Heating, Engine and Boiler Tabulation Committee of the Institution of Civil Engineers. An attempt is made to summarize the methods of pressure or difference-of-pressure measurement which are or may be of interest to the engineer. The paper is very extensive and not suitable for abstracting. To show the field that it covers, the part listing the methods of pressure measurement will be reported here. The paper is of interest in that it describes not only the methods themselves but indicates

their reliability, and, in some cases, the best methods of operation. Extensive reference to other publications are given.

Methods of Pressure Measurement. There are two fundamental or standard methods by which the pressure of a fluid may be measured:

1 By balancing it against a column of fluid of known vertical height or density.

2 By balancing it against a piston of known area, which is loaded with a known weight and made frictionless by rotation or otherwise.

These two methods (and their variations and combinations), which involve weight and length measurements only, provide the ultimate standards against which all other methods of measuring pressure are standardized and checked.

Instruments based on other methods of measuring pressure than the two fundamental methods outlined above have been developed in response to the need for cheapness, portability, and other special desiderata. Such secondary methods involve the use of:

3 Special forms of liquid manometers, such as the curved-tube manometer, which have to be calibrated by method (1).

4 Elastic-walled vessels, such as the aneroid barometer and the Bourdon tube, the distortion of which is a measure of the applied pressure.

5 Flexible vessels, whose motion is controlled by springs or weights. All non-metallic diaphragm instruments are based upon this method.

6 Liquid-sealed bells, whose motion is controlled by weights, springs, floats, etc. (These can be used as primary standards if carefully made and measured and weighed. It is, however, usually most convenient to calibrate instruments based upon this method by method (1).

7 Vessels suspended about a knife edge or other frictionless support, and containing liquid which is displaced by the application of pressure to one of the liquid surfaces. The various forms of balanced manometer are based upon this method.

8 Elastic fluids, such as air, hydrogen, or water, whose diminution in volume is a measure of the pressure applied. This method is made use of in certain deep-sea sounding apparatus.

9 Plastic solids of standard size, shape, and material, whose deformation is a measure of the pressure applied to them. This method is made use of in measuring the extremely high pressures produced by the detonation of cordite, etc.

10 Materials or devices whose electrical or optical properties change when they are subject to pressure. (John L. Hodgson in *Transactions of the Institute of Marine Engineers*, vol. 36, Dec., 1924, pp. 487–522, 36 figs., original paper, and pp. 522–563, figs. 37–51, discussion, *dgA*)

THERMODYNAMICS (See also Engineering Materials: Cellular India Rubber Insulation)

Heat Transmission of Insulating Materials

REPORT of the Insulation Committee of the American Society of Refrigerating Engineers covering such matters as the principles of heat transfer; definitions, nomenclature and symbols; surface transfer of heat; the measurement of temperature; the plate method of testing insulating materials; the box method of determining heat transmission; the economic value of insulation; results of tests to determine heat conductivity of various insulating materials.

An extensive paper included in the report is devoted to the subject of surface transfer of heat, giving the present state of knowledge on this subject. The author recalls the experiments by Barratt and his own experiments. The latter have demonstrated the existence of thermal resistance at the junction of two parts of the same material. In making the tests described (Trans. A.S.M.E., vol. 41, 1919, pp. 605–621), a drop equal to about $4^1/_2$ per cent of the total drop from the hot end to the cold end of the same was observed.

Further information on this thermal drop between metal surfaces was obtained in experiments dealing with the thermal conductivity of iron stampings. Numerical data are given in the original article.

The subject of heat transfer from solids to fluids and fluids to solids is next discussed. The author has made tests which gave values of the heat lost by various surfaces in still and moving air, and the results obtained are shown in Table 1 in the original article. This table shows in the first place that adding one layer of thin asbestos to a plain tin surface will actually increase the heat loss so that, at a temperature drop (internal above room) of 40 deg. cent. (72 deg. fahr.), 37 per cent more heat will be dissipated. This shows clearly that if hot-air pipes are covered with asbestos a very material loss is thereby incurred instead of a saving, as is generally supposed to be the case. Care must be used, however, in employing these data in cases where a reasonable air motion exists in the form of forced air currents over the ducts. The increase of loss is due for the most part to the increased radiation produced by interchanging a good radiating surface with a poor one. An interesting point brought out in this work was that one layer of asbestos 0.40 in. thick, seven layers of 0.013-in. sheet asbestos applied loosely, or three layers of 0.25-in. air-cell asbestos applied to hot-air pipes will reduce the loss to approximately 75 per cent of that for a plain tin surface. Experiments have been made recently by the author for the purpose of checking up these losses and, in particular, securing values for the surface temperatures in each case. In general, the same conclusions hold as to the use of insulating coverings. The author plans to give a detailed account of these experiments in a separate contribution.

The last-noted fact was independently observed by V. S. Day at the University of Illinois and reported upon at the National Warm Air Heating and Ventilating Association at Columbus, Ohio, in June, 1919. Very elaborate investigations have been conducted by the Warm Air Furnace Research Staff at the University of Illinois, and their work is reported in Bulletin No. 117 by V. S. Day and in Bulletin No. 120 by Willard, Kratz, and Day of the Engineering Experimental Station of the University of Illinois. In these latter experiments, as well as in the above-cited ones by the author, no attempt has been made to differentiate between the processes by means of which the heat is lost. This was impossible, since no reliable values of the radiation and convection constants for the materials in question are available.

Economic thickness of insulation is defined as that thickness which will reduce to a minimum the sum of the expenses due to the heat passed through it plus the expenses of prevention. Although the problem is simple in its main consideration, yet it becomes complicated when considered in a more exact method and the various reactions which occur as the insulation thickness is varied are taken into account. An equation is next derived giving the value of the economic insulation in the most general terms. From this equation simpler forms can be and are derived to cover the various special applications. A graphical method is also offered based on the following: Since the economic thickness is that which gives the minimum yearly expense it follows that it also gives the maximum money saving over that money loss which would occur if there were no insulation. It is also recommended to have a standard of reference for the economic thickness of insulation. In general, the author is in favor of greater thickness insuring against the possible intangible expenses and investing in a money saver which is free from the uncertain element of operating efficiency. (P. Nicholls, Pittsburgh, Pa., pp. 53–59, 6 figs., and discussion pp. 59–63.)

Losses from pipes and coverings are discussed on the basis of previously published investigations. The conclusion to which the author comes is that great advantage may be gained by making an insulating wall of several separate components instead of constructing it of one continuous thickness.

The paper is of interest as it represents a collection of results obtained by what appears to be reputable investigators. (*Heat Transmission of Insulating Materials.* Report of the Insulation Committee, Annual Meeting 1922, revised to 1924, published by The American Society of Refrigerating Engineers. 114 pp., including bibliography of 20 pp. Paper on Surface Transfer of Heat by T. S. Taylor, Research Physicist, Westinghouse Elec. & Mfg. Co., pp. 11–24, 9 figs., *eA*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Test Code for Centrifugal and Rotary Pumps

Tentative Draft of a Code in the Series of Nineteen being Formulated by the A.S.M.E. Committee on Power Test Codes

THE Test Code for Centrifugal and Rotary Pumps has been developed by an Individual Committee, under the chairmanship of Prof. W. B. Gregory. The other members of this Committee are M. Spillman, Secretary, W. C. Brown, M. B. MacNeille, L. F. Moody, F. H. Rogers, and W. M. White. It is now presented to the members of the Society for criticism and comment.

The Committee on Power Test Codes was reorganized in 1918 by the Council of The American Society of Mechanical Engineers to revise and enlarge the Power Test Codes of the Society published in 1915. This Committee is composed of a Main Committee of twenty-five members, having for its chairman, Fred R. Low, Past President, and nineteen individual committees of qualified specialists. These last named committees are developing the test codes for the various prime movers and auxiliary apparatus which constitute power-plant equipment.

Suggestions for corrections and additions to this test code will be welcomed by the Committee and the Society from those who are specially interested in the manufacture and use of Centrifugal and Rotary Pumps. These comments should be addressed to the Chairman of the Committee, in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Introduction

1 This code for testing centrifugal and rotary pumps applies to tests for determining the performance of the pump only and does not apply to the performance of piping, driving apparatus, or other auxiliaries—for which the codes governing tests of such equipment should be followed—except as they may affect the results of the pump tests.

Object

2 The object of this code is to standardize the method of determining the pump efficiency and output.

Instruments and Apparatus

3 The instruments required for measuring the head of water and speed of pump are

(a) Pressure gage
(b) Vacuum gage
(c) Mercury column
(d) Revolution counter
(e) Tachometer

These instruments are described in detail in the Code on Instruments and Apparatus.

4 The instruments and apparatus for measuring the quantity of water depend upon the method to be used for this measurement and will be found also in the Code on Instruments and Apparatus.

Operating Conditions

5 The three elements constituting operating conditions are:

(a) The quantity of water delivered by the pump
(b) The total dynamic head
(c) The speed in revolutions per minute.

The designed operating conditions and the actual conditions may vary.

6 The speed should always be maintained as nearly constant and as nearly equal to the nominal designed speed as possible. The prevailing total dynamic head under operating conditions may or may not be the correct designed head. If possible this head should be brought to the designed value by suitable methods applicable to the local conditions of installation. Throttling by means of a valve in the discharge line is the most feasible means to raise the total head in case the operating head is less than the designed value, but there shall be no throttling of a valve in the suction line close to the pump.

7 Providing additional delivery openings in the discharge mains at a lower elevation will usually allow the total head to be brought to the designed value. [Example: Opening hydrants in a system of street mains.] Care shall be taken to blank off any side outlets in order to prevent any leaks between the pump and the point of measurement of discharge.

8 Each of the various measurements for a given run shall be computed by averaging a series of instantaneous readings taken simultaneously at equal time intervals. Notations shall be made of extreme fluctuations at any instant. A sufficient number of readings shall be taken in making an observation so that the addition or elimination of a single reading representing a maximum swing of the instrument shall not affect the average by more than one per cent.

Hydraulic and Mechanical Conditions

9 The unit shall be in the best possible mechanical condition, with all bearings, stuffing boxes, and internal running clearances properly adjusted. The water to be handled shall be clear, cold water free from air, gases, or suspended solids. It is especially recommended that all air leaks in the suction pipe be eliminated and that the pump be free of foreign matter before the tests are started. The formulas given in this code are based on the use of water having a specific gravity of unity. Unless otherwise stipulated, the temperature of the water during the test shall not exceed 85 deg. fahr. For pumps handling some fluid other than water, suitable corrections shall be made depending on the characteristics of the liquid pumped. Additional tests shall be made to determine the relative specific gravity and viscosity as referred to water, also the boiling point. In the case of pumps handling solids in suspension, the dry weight and volume of the solids as well as the total weight and volume of the mixture are to be determined.

Duration of Test

10 The duration of the test depends on the method of driving the pump and on the method used to measure the discharge. It also depends on how completely the pump characteristic is determined. Since guaranteed conditions generally cover only one point in the head, speed, and capacity characteristics, it is recommended that data for additional points on these curves be taken when special information is desired. In these additional tests the capacity should be varied in steps covering a range of at least 10 to 15 per cent above and below the normal tested delivery of the pump and curves plotted of the results. This procedure gives complete pump characteristics and furnishes a check on the separate tests in the smoothness of the two separate curves (Head-Capacity and Shaft hp-Capacity).

Standard Units for Volume, Head, and Power

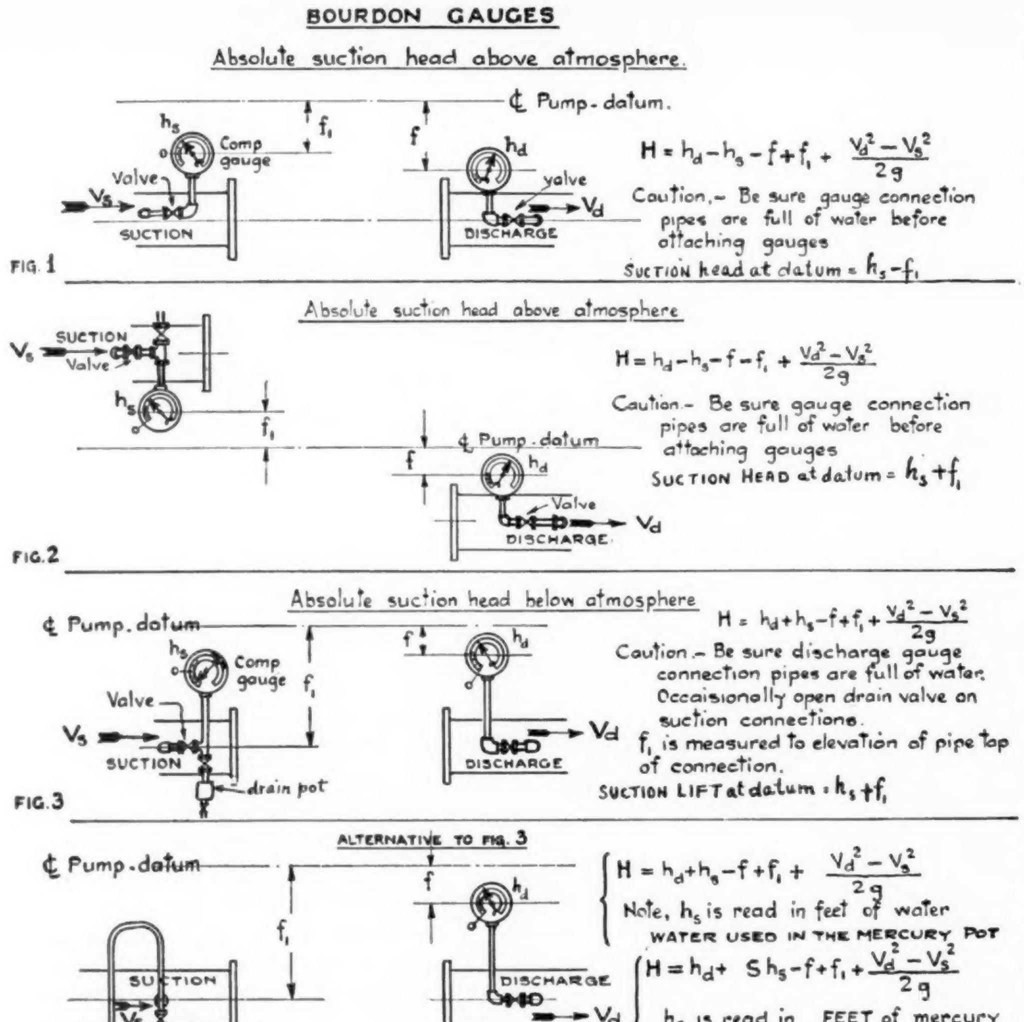
11 The standard unit for volume shall be the U. S. gallon or the cubic foot. The gallon unit shall be expressed in gallons per minute (g.p.m.) or million gallons per day of 24 hours (m.g.d.). The cubic-foot unit shall be expressed in cubic feet per second. The standard U. S. gallon contains 231 cu. in.

12 For temperatures not exceeding 85 deg. fahr. the specific gravity may be taken as unity. (At 85 deg. the specific gravity equals 0.9957 exactly.)

13 7.48 gal. is equal to 1 cu. ft. and 448.8 gal. per min. is equal to 1 cu. ft. a second. 694.4 gal. per min. is equal to 1,000,000 gal. per day of 24 hours.

14 The unit for measuring head shall be the foot. The relation between a pressure expressed in pounds per square inch and that expressed in feet of head is 1 lb. per sq. in. = 2.31 ft. (water) when the specific gravity of the liquid is unity. (1 inch of mercury = 1.132 ft. of water.)

15 In reading gages calibrated in pounds per square inch, when other than water is handled, or when the temperature of the water is such that the weight per cubic foot is greater or less than 62.35 lb., it is necessary to divide the reading in pounds per square inch by the specific gravity and to multiply by 2.31.



Note: When these sketches are redrawn for the final printing of this code the following caution will be attached to Figures 3 and 3a: *Caution*—Be sure gage connection pipes are full of water. Occasionally open drain valve on suction connections to free pipes of water.

Example: 100 lb. per sq. in. pressure on brine of 1.25 gravity is equivalent to 185 ft. head; the same pressure on oil of 0.85 gravity is equivalent to 272 ft. head; and a like pressure of 100 lb. per sq. in. on water at 210 deg. fahr. having a gravity of 0.96 is equivalent to 240 ft. head.

16 The unit for measuring power shall be the horsepower (550 ft-lb. per sec.) delivered to the pump shaft and designated as shaft horsepower (s.hp.).

17 *Measurement of Quantity of Water.* Methods of water measurement are divided into primary and secondary methods according to whether the method is in itself an absolute measurement of quantity or merely the measurement of an effect of quantity or rate of flow. Of these methods the only primary methods are those of measurement by volume or weight.

18 Secondary methods are more generally used in practice. These are measurements by weir, venturi meter, nozzle, or pitot tube. (The Code on Instruments and Apparatus describes the correct way to use each particular instrument.) Practically all these instruments involve a coefficient whose value and range of application are really well known, but if not they should be determined by a separate test.

19 No instrument or apparatus should be installed in such a way as to effect a change in either the coefficient of the instrument or the performance of the pump.

20 *Measurement of Head.* The net total head is the total dynamic head produced by the pump and is represented by the difference between the absolute heads at the discharge and suction nozzles, taking into account any difference between the elevations of these nozzles with respect to a fixed datum and any difference between the velocity heads at the points of measurement.

21 The standard method of measuring head shall be to employ a water column or gage glass giving a direct reading of surface elevation. Where this cannot be used, indirect methods may be employed, such as the use of a mercury or other fluid gage or a Bourdon dial gage. When water columns are used, care shall be taken to avoid errors due to the difference between the temperature of the water in the gage connection and that of the water in the pump by frequently draining the connection or determining the necessary correction.

22 Every gage or pressure-measuring device must be attached by a pipe or hose of smooth bore, having a diameter of 1/8 to 1/4 in., whose axis is at right angles to the direction of flow. The end of the connecting tube or pipe must be flush with the inside of the conduit of which the pressure is to be measured.

Note: The length of the smooth drilled portion of the hole should not be less than its diameter and the hole or holes when measuring fluids in motion should be located in a portion of the container in which the fluid has moved, is moving, and will move in a straight line for such distance that the pressure at the point of reading is not affected by the pressure, due to the centrifugal force of the fluid having changed or approaching a change in direction. In the case of a circular pipe not machine bored, it is suggested that not less than four such openings and connections be made at points about equally spaced around the circumference of the pipe.

23 The registration it shows is that part of the total energy in the flowing liquid represented by the static pressure and does not include the energy required to produce the velocity of flow.

24 It follows, therefore, with the suction and discharge velocities equal and the suction and discharge gages at the same elevation, that the true total dynamic head is the difference in absolute pressure that these gages register. All commercial pressure gages of the Bourdon type are calibrated in pressures above atmospheric,

so that to obtain absolute pressures it is necessary to add the atmospheric pressure to the readings of both gages.

25 Where accuracy is desired it is recommended that mercury manometers be used instead of Bourdon gages when the head against which the pump is operating is 50 ft. or less. When Bourdon gages are used it is recommended that drain cocks be placed immediately below the gages and that frequent tests be made to determine that the pipe connections of the gage are full of water. Mercury gages shall be calibrated under the actual conditions of temperature, specific gravity, etc. prevailing in the test by comparing the gage reading with the height of a water column. With any form of gage care shall be taken to eliminate any leaks in the connecting piping, even if small, and to avoid the trapping of air in the connecting pipe or hose.

The total dynamic head H may be expressed by means of a formula:

Let

h_d = discharge-gage reading in feet corrected to elevation

h_a = atmospheric-pressure head in feet corresponding to the barometer

H_d = $h_d + h_a$ = absolute discharge pressure head in feet

h_s = suction-gage reading in feet corrected to elevation

H_s = $h_s + h_a$ = absolute suction pressure head in feet

V_d = mean discharge velocity in feet per second

V_s = mean suction velocity in feet per second

Then

Net total head =

(Head equivalent to total energy of discharge) — (Head equivalent to total energy of suction)

or

$$H = \left(H_d + \frac{V_d^2}{2g}\right) - \left(H_s + \frac{V_s^2}{2g}\right)$$

$$= H_d - H_s + \frac{V_d^2 - V_s^2}{2g}$$

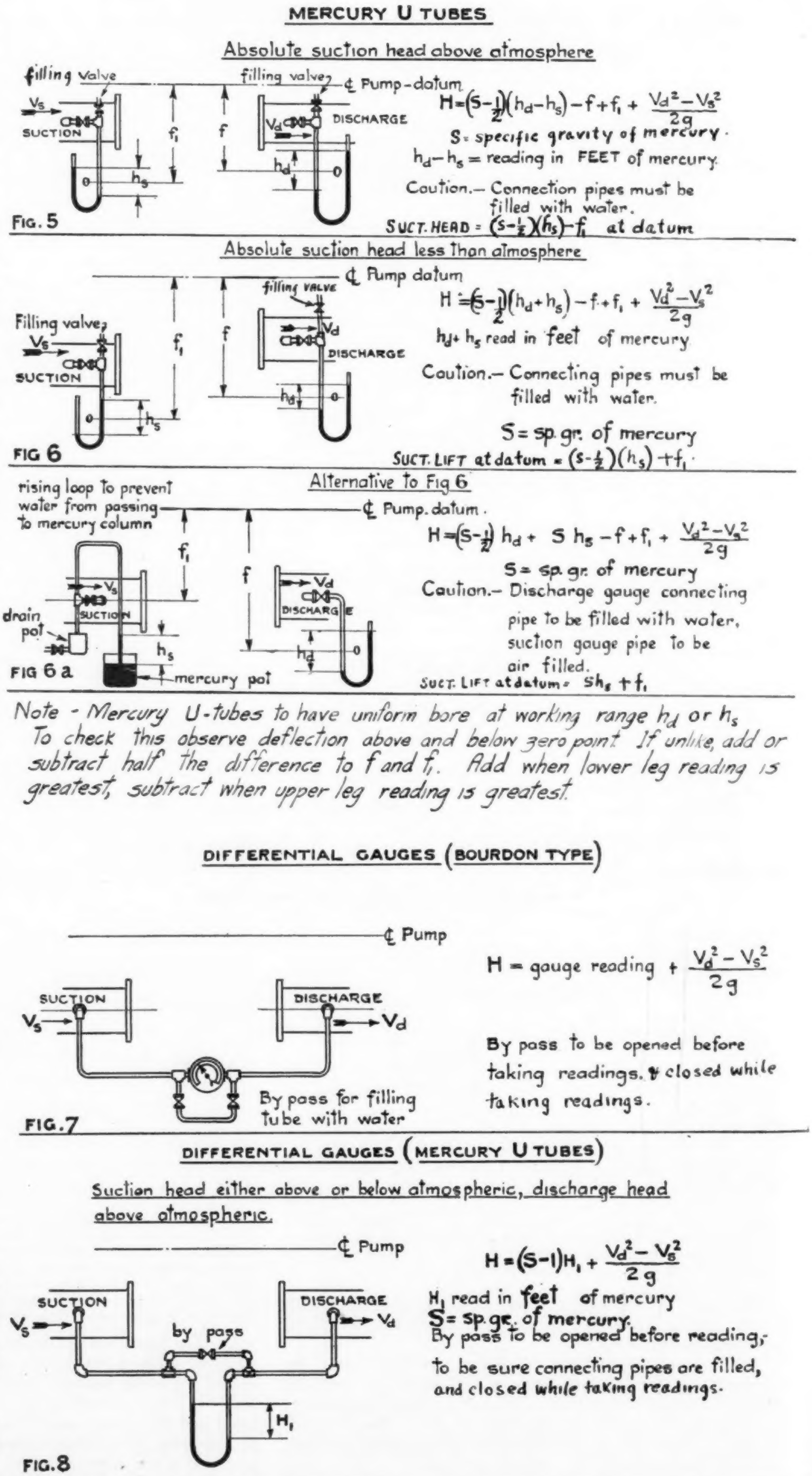
With Bourdon gages see Figs. 1 and 4.

If mercury U-tubes are used the procedure is the same. See Figs. 5, 6, and 7.

For differential gages (Bourdon type) the gage reads exact value of $H_d - H_s$. See Fig. 8.

If a mercury U-tube be used as a differential care must be exercised that all the connections are either entirely filled with water or entirely filled with air. See Figs. 9 and 10.

26 *Measurement of Speed.* The speed of the pump shall be taken by a revolution counter or an accurately calibrated tachom-



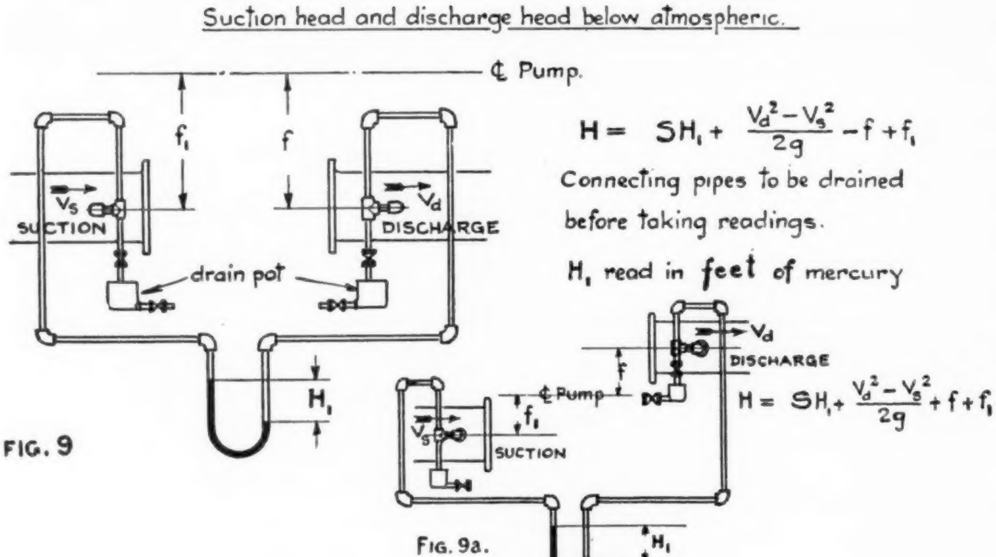


FIG. 9

FIG. 9a.

WATER GAUGES AND U TUBES

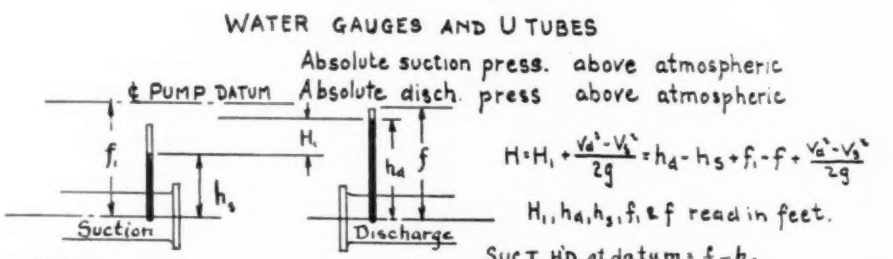


FIG. 10

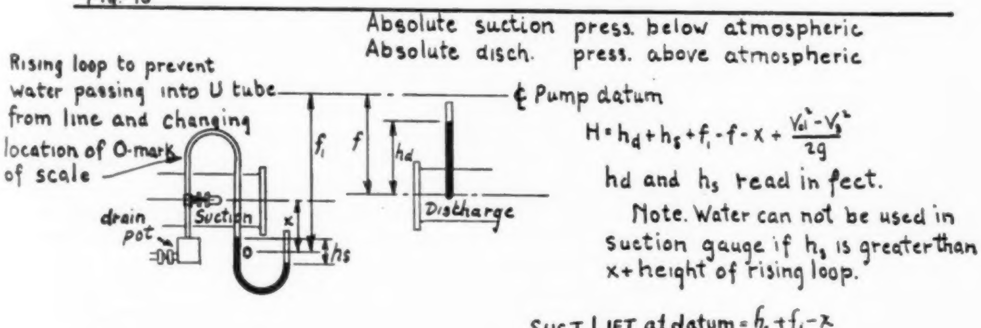


FIG. 11

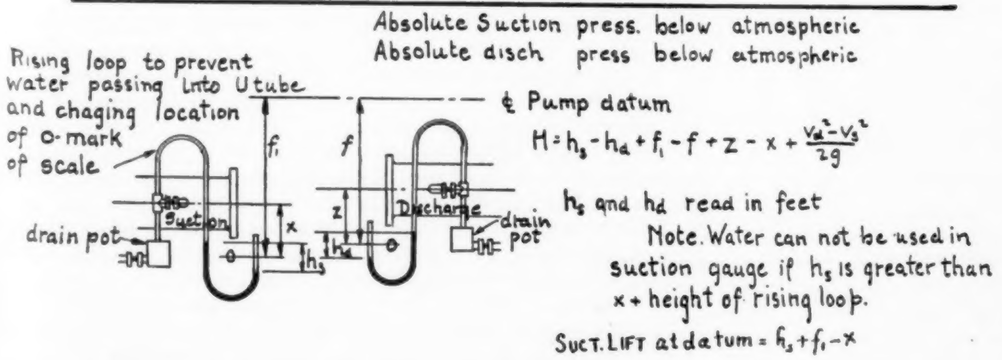


FIG. 12

eter. An accurate measurement of speed shall be considered essential.

27 *Measurement of Power Input.* Measurement of power input to the pump, that is, the shaft horsepower (s.hp.) of the pump, falls into two general classes. Some measurements are those which in themselves determine the actual power or torque delivered to the pump and are therefore made entirely during the test, using some form of transmission dynamometer. Other measurements are those which involve measurement, during the pump test, of power input to the driving element and the previous or subsequent determination of the relation of the power input to the power output of this driving element under the identical conditions of the pump test. (Efficiency or calibration of the driving element.)

28 The power delivered to the pump shaft when directly connected shall be the power output of the driving element as determined by the code prepared for the test of that driving element. When not directly connected corrections shall be made for the losses between the driving element and the pump.

29 *Calibrated Electric Motors.* If a transmission dynamometer is not available the preferred method of determining power input to the pump shall be the use of a direct-connected calibrated electric motor, provided the calibration tests of this motor are made in strict accordance with the standard rules of the American Institute of Electrical Engineers and are frequently rechecked. Curves shall be made up from the calibration tests translating kilowatts input into shaft-horsepower output. Power input to the motor during a pump test shall then be made in accordance with the standard rules of the American Institute of Electrical Engineers and the corresponding power output as shown on the calibration curve shall be taken as the power input to the pump.

30 The foregoing procedure will also apply to field tests of pumps where manufacturers' ratings of the motor have been determined by actual tests made in accordance with the above-mentioned rules and certified by the manufacturer. In any case where a calibrated motor is to be used the power conditions shall not be allowed to vary or to differ from those under which the calibrations were made by an amount great enough to introduce into the test inaccuracies greater than those involved in the calibration.

31 When the method of test as outlined above cannot be employed, other methods as outlined in the codes covering each particular type of driving unit can be agreed upon.

CALCULATION OF RESULTS

32 *Water Horsepower.* The water horsepower (w.hp.) is found by the following formula:

$$\text{w.hp.} = \frac{Q \times W \times \text{total head in feet}}{550}$$

where

Q = number of cubic feet per second
W = weight of water in pounds per cubic foot

When the weight of water is 62.35 lb. per cu. ft. (Density at standard temperature of 62 deg. fahr.)

$$\text{W. hp.} = \frac{\text{g.p.m.} \times \text{total head in feet}}{3960}$$

33 *Efficiency.* The efficiency of a pump is the ratio of the energy converted into useful work to the energy supplied to the pump;

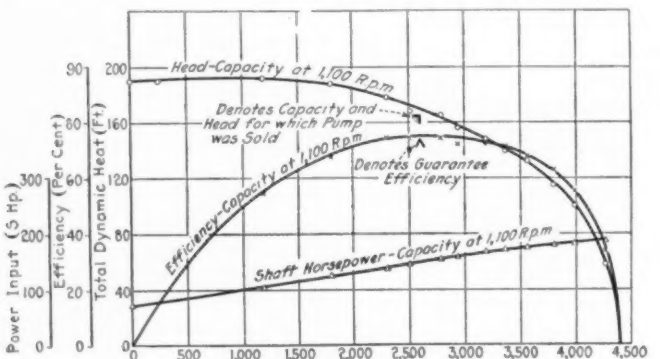


FIG. 13 SAMPLE PLOT SHOWING CHARACTERISTIC CURVES FOR A TEST WHERE THE DATA HAS BEEN CORRECTED TO CONSTANT SPEED OF 1100 R.P.M.

that is, the ratio of the water-horsepower output to the shaft-horsepower input, or

$$\text{Efficiency in per cent} = \frac{\text{w.hp.}}{\text{s.hp.}} \times 100$$

where the values have been determined as described in the previous paragraphs.

RECORDS

34 It is customary to present the results of a test in the form of a single sheet upon which are drawn three curves expressing respectively the relation between (*a*) efficiency and capacity, (*b*) head and capacity, and (*c*) shaft horsepower and capacity. The values used in plotting these curves are those computed for a given definite speed of the pump, usually that at which the pump operates at best efficiency or that at which it was designed to operate.

35 When it is impossible to obtain the designed speed on test due to variation of frequency in the electric current or other causes, corrections in the capacity, head, and shaft horsepower to correspond to the designed speed may be made from test data. These corrections are based on the fact that within small differences in speed the capacities vary directly as the speeds, the heads as the squares of the speeds, and the shaft horsepowers as the cubes of the speeds where the speed variations do not exceed 3 per cent. Should the speed be more than 3 per cent off the normal, corrections based on the above rule can be made with consent of the interested parties.

36 The general data should be recorded as outlined in Pars. 25 to 36 of the Code on General Instructions.

37 If the pump under test is of the rotary displacement type, such as a gear pump, its volumetric displacement corresponding to the speed developed in the test may be computed, and the difference between this displacement and the quantity actually pumped may be stated as the slip, expressed as a percentage of the displacement.

TABLE 1 DATA AND RESULTS OF CENTRIFUGAL OR ROTARY PUMP TEST

GENERAL INFORMATION

(1)	Date of test	
(2)	Location	
(3)	Owner	
(4)	Builder	
(5)	Test conducted by	
(6)	Object of test	
(7)	Builder	

PUMP DATA

(9)	Type: (Centrifugal or rotary, horizontal or vertical, shaft, split, or solid casing, enclosed or open-type impeller, single or multi-stage, spiral casing, with or without diffusion vanes, etc.)	
(10)	Rated capacity	
(11)	Rated head	
(12)	Rated speed	
(13)	Liquid pumped (clear, muddy or sandy water, or other fluid specific gravity, temperature, etc.)	
(14)	Method employed for measuring quantity of water	
(15)	Method employed for measuring power	
(16)	Method employed for measuring head	
(17)	Duration of period of measuring quantity of water	
(18)	Duration of period of measuring power	
(19)	Duration of period of measuring head	
(20)	Size of discharge outlet	
(21)	Size of suction inlet	
(22)	Time of service and general condition of pump	

DRIVER DATA

(23)	Type (motor, turbine, gear, belt, etc.)	
(24)	Name of builder	
(25)	Builder's type and serial number	
(26)	Rated conditions (horsepower, speed, electrical or steam conditions, etc.)	
(27)	Time in service	

RESULTS

(28)	Volume of water pumped	g.p.m.
(29)	Discharge head absolute	
	(*a*) Computed velocity in suction pipe at gage	ft. per sec.
	(*b*) Computed velocity in discharge pipe at gage	ft. per sec.
	(*c*) Head due to difference in velocity heads, plus or minus	ft.
(30)	Suction head, absolute	ft.
(31)	Total head on pump	ft.
(32)	Speed	r.p.m.
(33)	Water horsepower	hp.
(34)	Horsepower input to drive	hp.
(35)	Efficiency of drive	per cent
(36)	Shaft horsepower or horsepower input to pump	hp.
(37)	Pump efficiency	per cent
(38)	Plot (See Fig. 13)	
(39)	Test conducted by	
(40)	Observers	
(41)	Witnesses	

Telephone Poles to be Standardized

AN INTERESTING instance of the organized use of experts in the wood-using industries to reduce the serious waste of our forest products, referred to by President Coolidge in his address to the National Conference on the Utilization of Forest Products, is the organization of a large committee of technical experts to develop national specifications for wood poles. The U. S. Forest Service considers that standardization of forest products is basically important as a means to economy in timber utilization.

As the annual cost of poles is over $10,000,000, savings due to standardization are likely to be very large.

These are the poles commonly used for telephone and telegraph lines, and produced to the extent of something over three million during 1923 for the use of steam and electric railways, electric light and power companies. Cedar is the wood principally used, with chestnut and oak, pine, and cypress next. The sponsors for this project under the procedure of the American Engineering Standards Committee, are the United States Independent Telephone Association and the Bell Telephone System, both of which have an important interest in developing specifications that will assure quality and economy in the utilization of wood poles for line construction.

The questions to be considered by the committee include items of form, such as diameter, taper and length of poles; the specification of defects with respect to decay, knots, etc. an important point in increasing the efficiency of utilization of forest products by not requiring the elimination of poles having unessential faults; methods of manufacture; inspection; and expression of the strength values or loads that can safely be sustained by the poles in service. The sectional committee decided upon the organization of six sub-committees, on western cedar poles, eastern cedar poles, chestnut poles, southern pine poles, strength values for all species, and definitions for the guidance of sub-committees preparing specifications. Other committees of the A.E.S.C. have given consideration to questions involving the strength of wood poles and a special study will be made to the end of correlating the recommendations of these groups.

Safety Code for Elevators, Dumbwaiters, and Escalators

Abstract of Second or Revised Edition of Code Originally Published in 1921

FOLLOWING the publication of the Safety Code for Elevators by The American Society of Mechanical Engineers in January, 1921, and at the request of that society the American Engineering Standards Committee authorized the organization of a Sectional Committee under its procedure. This Committee, which is sponsored by the American Institute of Architects, the Bureau of Standards, and the A.S.M.E., held its first meeting on November 20, 1922, and since by frequent meetings and conferences has completed the first revision of the original code.

This revised Code has received the unanimous approval of the Committee and is now before the three sponsor bodies for approval and transmission to the A.E.S.C. for approval as an American Standard. Accordingly the A.S.M.E. Standardization Committee takes pleasure in presenting an abstract of the revised Safety Code for Elevators for the information of the members of The American Society of Mechanical Engineers, such publication being part of the Society's procedure for approval and adoption of standards and codes.

In preparing this abstract only the more important requirements covering passenger elevators have been reproduced. Under separate sections, however, the Code contains rules for freight elevators, dumbwaiters, and escalators, as well as rules for inspection, maintenance, and operation. Due to a similarity of requirements, it was not deemed necessary to abstract any of the rules under these latter sections.

Introduction to Code

THE first edition of this Code, prepared by the Sub-Committee on Protection of Industrial Workers of The American Society of Mechanical Engineers with the assistance of representatives of a number of interests, including manufacturers, insurance carriers, regulatory bodies, and technical societies, was published in January, 1921. This Code was drawn because of the need for uniform regulation covering the hazards of elevator operation. It was widely circulated and has been used as the basis for several state and municipal codes.

The preparation of this second edition has been conducted under the rules of procedure of the American Engineering Standards Committee. The sponsorship was widened to include the American Institute of Architects and the U. S. Bureau of Standards, both of which organizations had an active part in the formulation of the first edition.

This Code is one of a series of safety codes on various subjects which have been or are being formulated under the general auspices of the A.E.S.C. It is intended as a guide to state and municipal authorities and may be adopted by them in whole or in part. It is also intended for use as a standard of reference for safety requirements for the use of elevator manufacturers, architects, and consulting engineers. For this purpose it may be used to advantage in connection with the development of standards for elevator construction by a Sectional Committee under the A.E.S.C. procedure. It is also intended as a safety standard for use by hotels, department stores, office buildings, and other users of elevators through voluntary application.

While this revision of the Code closely follows the first edition in form and requirements, there has been a rearrangement of some of the material in Parts 1, 2, and 3, making the order of presentation somewhat more logical.

New material has been included in several places, notably under Definitions and the various sections on safeties, terminal stopping devices, and buffers.

A system of key numbers has been added to indicate whether a rule should be made retroactive, and if so, how long a period after the adoption of the Code should be permitted to bring the equipment in question up to the Code requirements.

NOTE: This key is given as the Committee's recommendation for average conditions. The exact application of these rules will depend largely on the age and condition of the majority of the elevators within a given jurisdiction. In older settled cities and states, where the average age of all elevator installations is high, it will not be practical to make many of the rules retroactive, while in some of the cities and states, notably in the Middle and Far West, where most of the elevators are of comparatively modern design and where the average age of all installations is low, a much larger part of the code might be applied to existing installations without working hardship to present owners of equipment.

A local committee including representatives of elevator-construction companies, architects, builders, casualty-insurance companies and city or state inspectors thoroughly familiar with local conditions might well determine which parts of the Code shall be made retroactive. The suggested application as given in the key could well be used as a starting point for the work of such a committee.

An inspector's handbook giving the Code material of special interest to inspectors and maintenance and repair men, and a full discussion of the quoted rules, is contemplated as a separate publication.

The Sectional Committee will be glad to receive criticisms of the Code requirements and suggestions for its improvement, especially such as are based on actual experience in the application of the rules. It is expected to issue revised editions from time to time with such changes as wide experience and improvement in the art may dictate.

SECTION 1 SCOPE AND PURPOSE

RULE 10 SCOPE

a This Code of safety standards covers the construction, maintenance, and operation of elevators, dumbwaiters, escalators, and their hoistways except as stated in the following paragraph.

b This Code does not apply to belt, bucket, scoop, roller or similar inclined or vertical freight conveyors, tiering or piling machines, skip hoists, wharf ramps or apparatus in kindred classes, amusement devices, stage lifts or lift bridges, elevators of capacity exceeding 30,000 pounds and platform area exceeding 300 square feet when suspended by cables near each corner of the hoistway and at additional positions, nor to elevators used only for handling building materials and mechanics during the building construction. These types of apparatus should be made subject to suitable specifications for each type.

NOTE: The Code recognizes the deteriorating influence of wear, rough usage, and the atmospheric conditions under which elevator apparatus, particularly door locks, interlocks, and electric contacts, are required to operate. In the design and installation of such apparatus due regard must be given to these conditions and to the part of the structure upon which such apparatus is mounted.

RULE 11 PURPOSE, INTERPRETATION, AND EXCEPTIONS

The purpose of this Code is to provide reasonable safety for life and limb. In case of practical difficulty or unnecessary hardship the enforcing authority may grant exceptions from the literal requirements or permit the use of other devices or methods, but only when it is clearly evident that reasonable safety is thereby secured.

NOTE: It is suggested that in cases where exceptions are asked for the enforcing authority consult with the Sectional Committee on a Safety Code for Elevators, care of American Engineering Standards Committee, 29 West 39th Street, New York, N. Y. or care of the Secretary of the Committee, Bureau of Standards, Washington, D. C. Such inquiries will be referred to a Standing Committee on Research, Approval, and Interpretations, who will be glad to advise as to the intended meaning of any code requirement or to suggest modifications in particular cases where such suggestions are desired. Such consultation will tend to bring about uniform application of the Code and will keep the committee informed of criticisms which should be considered in future revisions of the Code.

SECTION 2 DEFINITIONS

Elevator. An elevator is a hoisting and lowering mechanism equipped with a car or platform which moves in guides in a substantially vertical direction.

NOTE: Dumbwaiters, endless belts, conveyors, chains, buckets, etc., used for the purpose of elevating materials, and tiering or piling machines operating within one story, are not included in the term "Elevator."

Dumbwaiter. A dumbwaiter is a hoisting and lowering mechanism equipped with a car, the floor area of which does not exceed nine (9) square feet, whose compartment height does not exceed four (4) feet, the capacity of which does not exceed 500 pounds, and which is used exclusively for carrying freight.

Escalator. An escalator is a moving inclined continuous stairway or runway used for raising or lowering passengers.

Hoistway. A hoistway is any shaftway, hatchway, well hole, or other vertical opening or space in which an elevator or dumbwaiter is designed to operate.

Top Clearance. Top clearance of the elevator car is the distance the car floor can travel above the level of the upper terminal landing without any part of the car or devices attached thereto coming in contact with the overhead structure.

Top clearance of the elevator counterweight is the shortest vertical distance between any part of the counterweight structure and the nearest part of the overhead structure or any other obstruction when the car floor is level with the lower terminal landing.

Bottom Clearance. Bottom clearance of the elevator car is the vertical distance between any obstruction in the pit, exclusive of the compensating device, buffers, and buffer supports, and the lowest point on the understructure of the elevator car, exclusive of the safeties, car-frame channels, and guide shoes, when the car floor is level with the lower terminal landing.

Top Overtravel. Top overtravel of the elevator car is the distance provided for the car floor to travel above the level of the upper terminal landing until the car is stopped by the normal terminal stopping device.

Bottom Overtravel. Bottom overtravel of the elevator car is the distance the car floor can travel below the level of the lower terminal landing until the weight of the fully loaded car rests on the buffers, and includes the resulting buffer compression.

Bottom overtravel of the counterweight is the distance the counterweight can travel below its position when the car platform is level with the upper terminal landing until the full weight of the counterweight rests on the buffers, and includes the resulting buffer compression.

Overhead Structure. The overhead structure is all of the elevator equipment, supporting structure, and platforms at the top of the hoistway.

Door Interlock. A door interlock is a device, the purpose of which is:

First: To prevent the operation of the elevator machine in a direction to move the car away from the landing:

- *a* Unless the hoistway door at which the car is standing is closed and locked (Floor Unit System); or
- *b* Unless all hoistway doors are closed and locked (Hoistway Unit System); and

Second: To prevent the opening of a hoistway door from the landing side; except by a key or special mechanism:

- *a* Unless the car is standing at rest at the landing; or
- *b* Unless the car is coasting past the landing with its operating device in the "STOP" position.

Note: The interlock shall not prevent the movement of the car when the emergency release hereinafter described is in temporary use.

Emergency Release. An emergency release is a device the purpose of which is to make inoperative door or gate electric contacts or door interlocks in case of emergency.

Elevator Car. An elevator car is the load-carrying unit, including its platform, car frame, and enclosure, if any.

Rated Load. The rated load of an elevator is the load in pounds which the elevator is designed and installed to carry in accordance with this Code.

Rated Car Speed. The rated car speed is the average of the maximum speeds attained, in the up and down direction with 50 per cent of the rated load in the car, in making a full run.

Maximum Car Speed. The maximum car speed is the greatest speed attained in the down direction with any load up to and including the rated load in the car.

Control. The control of an elevator or dumbwaiter consists of the device or assemblage of devices which controls the delivery of power to the hoisting machine.

Operating Device. The operating device of an elevator or dumbwaiter is the car switch, push button, rope, wheel, lever, treadles, etc. employed to enable the operator to actuate the elevator control.

Normal Terminal Stopping Device. A normal terminal stopping device is an automatic device for stopping the elevator car within the overtravel, independent of the operating device.

Final Terminal Stopping Device. A final terminal stopping device is an automatic device for stopping the car and counterweight from governor tripping speed, within the top clearance and bottom overtravel, independent of the operation of the normal terminal stopping device, the operating device, and the buffers.

Buffer. A buffer is a device designed to absorb the impact of the car or counterweight at the extreme limits of travel.

Car-Leveling Device. A car-leveling device is any mechanism or control which will move the car within a limited zone, toward and stop the car at the landing.

Note: A car-leveling device may also be used for emergency operation of the car throughout its entire travel and for safe-lifting purposes.

Part 1 Hoistway Construction for Passenger and Freight Elevators and for Dumbwaiters

SECTION 10 HOISTWAY CONSTRUCTION

Rule 100 Fire-Resisting Hoistway Enclosures

Rule 101 Non-Fire-Resisting Hoistway Enclosures

Rule 102 Clearance between Cars, Counterweights, and Hoistway Enclosures of Power Elevators

Rule 103 Pits, Overtravel, and Clearances

[The requirements under this rule are the same as in the first edition of the Code but differently arranged.—Editor.]

Rule 104 Hoistway Windows, Penthouses, and Machine Rooms

Rule 105 Machine Supports, Loads on Supports, and Factors of Safety

[In computing loads on overhead beams and other supports, the Code now requires that the sum of the tensions on all of the cables suspended from the supporting beams shall be doubled to allow for impact, acceleration, etc. and this amount added to the weight of the sheaves and beams (and the machine, controller, etc. if located overhead). The factors of safety shall be not less than five (5) for steel, seven (7) for concrete, and nine (9) for timber.—Editor.]

SECTION 12 LANDINGS

Rule 120 Hoistway Doors for Passenger Elevators

Rule 121 Door Interlock

a A door interlock shall prevent, first, the normal operation of the car:

Unless the hoistway door at which the car is standing, is closed and locked (Door Unit System); or

Unless all hoistway doors are closed and locked (Hoistway Unit System)

Exception: The interlock shall not prevent the movement of the car when the emergency release is in temporary use, or when the car is being moved by a car-leveling device.

and secondly, shall prevent opening the hoistway door from the landing side except by a key or special mechanism;

Unless the car is standing at the landing; or

Unless the car is coasting past the landing with its operating device in the "STOP" position.

b The functioning of a door interlock to prevent the movement of the car shall not be dependent upon the action of a spring or springs in tension, nor upon the closing of an electric circuit.

c A hoistway door or gate shall be considered closed and locked when within four (4) inches of full closure, if at this position and any other up to full closure the door or gate cannot be opened from the landing side more than four (4) inches.

d If a door closer of a type that will eventually lock the door is used, the interlock may permit the starting of the elevator car when the door is within three (3) inches or less of full closure, provided the door can again be opened up to four (4) inches from full closure from any position within this range except that of full closure.

e Each type and make of door interlock shall be tested and approved by some competent designated authority.

RULE 122 DOOR OR GATE ELECTRIC CONTACTS

Part 2 Power Passenger Elevators

SECTION 20 GUIDES, BUFFERS, AND COUNTERWEIGHTS FOR POWER PASSENGER ELEVATORS

RULE 200 GUIDE RAILS

RULE 201 CAR AND COUNTERWEIGHT BUFFERS

[The Code gives limiting values of retardation of the car under the action of buffers; for spring buffers this has been set at 80.5 feet per second per second (two and one-half times gravity) and at 64.4 feet per second per second for oil-type buffers. Total stroke of buffer must be sufficient to allow for 32.2 feet per second per second retardation.—EDITOR.]

SECTION 21 CAR CONSTRUCTION AND SAFETIES FOR POWER PASSENGER ELEVATORS

RULE 215 CAR SAFETIES AND SPEED GOVERNORS

[All passenger and freight elevators suspended by cables must be provided with a safety device capable of stopping and sustaining the car with rated load. The application of the safeties shall be by means of a speed governor, the operation of which, to set the safety, shall be at a speed of not less than 115 per cent of the maximum car speed. The maximum retardation with safeties of the clamping type (usually occuring with the minimum load in the car), averaged over the entire safety slide, shall not exceed 64.4 feet per second per second (twice gravity retardation).

[It is recommended that manufacturers submit each type and size of safety which they make to some designated authority for test and approval, the approving authority to furnish for each type and size of safety a certificate stating the range of allowable weight and speed, the stopping distances for full load and no load, and the various combinations of weights and speeds for which it is certified.

[Instantaneous types of safeties are limited to a car speed of not in excess of 125 feet per second.—EDITOR.]

RULE 216 CAR SAFETY TESTS

a A rated-capacity test of the safeties shall be made of each new elevator before the elevator is placed in regular service. This test shall be made to determine whether the safety will operate within the allowable limits of the maximum and minimum retardation. The minimum slide shall be not less than that shown by curve Fig. 1, and the maximum slide shall be not greater than that shown by curve Fig. 2 [Figs. 1 and 2 not reproduced here.—EDITOR], corresponding to the car speed in feet per minute at the beginning of retardation.

NOTE: These requirements determine a limiting ratio between the weight of the car and the weight of the load.

b Car safeties shall be periodically inspected and tested to determine the condition of the sliding surfaces and the working parts. These tests shall be made at least once a year at rated speed (not necessarily with full load) to determine if the device is in operating condition.

RULE 217 CAPACITY AND LOADING

[The first edition of the Code required a minimum rated load of 75 pounds per square foot of effective car-floor area for power passenger elevators. It was found in practice, however, that for large cars—as, for example, the elevator cars in subways and railway stations—the loadings were considerably in excess of this figure. In the revised Code the minimum rated load varies with the area of the car floor from a minimum of 60 pounds per square foot to 100 pounds per square foot for cars having a car area of 120 square feet or over.—EDITOR.]

SECTION 22 MACHINES AND MACHINE SAFETIES FOR POWER PASSENGER ELEVATORS

RULE 220 MACHINES AND MACHINERY

a Drums and leading sheaves shall be of cast iron or steel, and shall have finished grooves. U-grooves shall be not more than one-sixteenth ($^1/_{16}$) inch larger than the cables.

b The factors of safety based on the static loads (the rated load plus the weight of the car, cables, counterweights, etc.) to be used in the design of elevator hoisting machines shall be not less than:

8 for wrought iron or wrought steel
10 for cast iron, cast steel or other materials

c Set-screw fastenings shall not be used in lieu of keys or pins.

d No friction gearing or clutch mechanism shall be used for connecting the drums or sheaves to the main driving gear.

e No belt or chain-driven machine shall operate any passenger car.

f Worm gearing having cast-iron teeth shall not be used for passenger elevator machines.

g Winding-drum and traction machines for passenger elevators shall be equipped with brakes applied automatically by springs or gravity when the control is at the "STOP" position. Electric passenger-elevator machines shall be equipped with electrically released brakes.

The brakes shall not be released until power has been applied to the motor, except when the rated load will not, within the limits of travel, accelerate the car speed above 150 per cent of rated speed.

h In normal operation the action of the brake magnet in allowing the brake to set shall not be prevented from occurring in the intended manner by any single ground or short-circuit nor by any counter voltage.

During all emergency stops the action of the brake magnet in allowing the brake to set shall not be retarded by motor field discharge or counter e.m.f. nor by any single ground or accidental short-circuit.

RULE 221 HYDRAULIC MACHINES

RULES 222 AND 323 TERMINAL STOPPING AND SAFETY DEVICES

[These rules have been revised to call for two terminal stopping devices, either of which will stop the elevator independently of the other. The final terminal stopping device must be arranged to stop the elevator from governor tripping speed independently of all other safety devices. The rules specify in detail the types of normal and final terminal stopping devices which must be provided for each type of elevator.—EDITOR.]

RULES 223 AND 324 CONTROL

[Two new paragraphs have been added to this rule requiring the controlling device on all elevators operated by hand-operated cable to be arranged so that if the power fails it will be necessary to return the controlling device to the off position before the elevator can again be started, and requiring that overload circuit breakers used in connection with direct-current elevators be arranged to open the circuit of the brake magnet coil winding at the same time that the line circuit is opened.—EDITOR.]

SECTION 23 CABLES AND SIGNAL SYSTEMS FOR POWER PASSENGER ELEVATORS

RULES 230 AND 330 CABLES

[An increasing factor of safety for car and counterweight cables is required by the Code, depending on the speed of the elevator. For passenger elevators the minimum factor of safety is approximately 7 and for freight elevators approximately 6. It is recommended that the factor of safety be increased 25 per cent when machines of the traction type are used in order to allow for wear on the cables.—EDITOR.]

Definition of "Engineer"

"THE engineer," said Marcus Vitruvius (B.C. 150), "should be a good writer, a skilful draftsman, versed in geometry and optics, expert at figures, acquainted with history, informed on the principles of natural and moral philosophy, somewhat of a musician, not ignorant of the sciences, both of law and physics, nor of the motions, laws, and relations to each other of the heavenly bodies. . . . . Moral philosophy will teach him to be above meanness in his dealings and to avoid arrogance. It will make him just, compliant, and faithful to his employer, and what is of the highest importance, it will prevent avarice gaining an ascendency over him, for he should not be occupied with thoughts of filling his coffers nor with the desire of grasping everything in the shape of gain, but by the gravity of his manners and a good character should be careful to preserve his dignity."

Engineering and Industrial Standardization

New Activities of the A.E.S.C. Preferred Numbers Committee

L. P. ALFORD, Editor of *Management and Administration*, and former Vice-President of The American Society of Mechanical Engineers, has accepted the chairmanship of a Working Committee under the Preferred Numbers Committee, to study the principles of geometric series and the theory of preferred-number systems, with due consideration of the psychologic and economic questions involved in the development of a practical preferred-numbers scheme which it is hoped will find general adoption in American engineering and industry.

The Working Committee has the following membership:

- L. P. ALFORD, *Chairman* (representing Society of Industrial Engineers on the Preferred Numbers Committee), Editor, *Management and Administration.*
- L. A. HAZELTINE (representing Institute of Radio Engineers on the Preferred Numbers Committee), Professor of Electrical Engineering, Stevens Institute of Technology.
- F. T. LLEWELLYN (representing American Society of Civil Engineers on the Preferred Numbers Committee), office of the President, U. S. Steel Corporation.
- SANFORD A. MOSS (representing Society for the Promotion of Engineering Education on the Preferred Numbers Committee), Thomson Research Laboratory, General Electric Company.
- C. T. MYERS (representing the Society of Automotive Engineers on the Preferred Numbers Committee), Consulting Engineer, Rahway, N. J.
- WALTER I. SLICHTER, Professor of Electrical Engineering, Columbia University.
- F. R. STILL (representing The American Society of Mechanical Engineers on the Preferred Numbers Committee), Vice-President and Secretary, American Blower Company.

Each member of the committee has been assigned an individual subject for study, and will be asked to prepare a report thereon for consideration and adoption by the Working Committee. The following are the questions propounded for study and discussion of the members:

1 Can there be formulated a relation between the law of error in the selection of size series along such lines possibly as that errors of judgment, estimation, and measurement tend to be roughly proportionate to the quantity measured, hence economical spacing from the point of view of our lack of knowledge of the precise properties of the standardized object and of the requirements it has to meet in service, seem to call for geometric series?

2 Is it the case that many engineering decisions involve very large and often unrealized factors of doubt, such that the errors due to rounding of calculated sizes to the nearest preferred number may often be entirely negligible?

3 Assuming that in many cases the number of sizes which should exist between certain limits is often not subject to engineering calculation and is a matter on which trained judgment may differ widely, will preferred numbers provide a rational and convenient means of expediting decisions in such cases?

4 Will there be important savings in materials, labor, storage space, gages, containers, catalogs, sales cost, etc. if the number of sizes between required limits is reduced to a minimum by some sort of preferred-numbers system?

5 Will the use of preferred numbers have an economic value in design work by providing an easy means of applying the principle of dimensional similitude to intermediate sizes when end sizes are established or known, saving work in the drafting room and reducing the number of tools and gages involved in the designer's selection of sizes? (Compare wide use in Europe of "Standard Diameter" systems, even before the introduction of preferred numbers.)

6 Should there be any general principle set up providing for systematic or local change of spacing of series to suit (*a*) higher demand for certain sizes warranting larger stocks and closer fitting for such sizes, and (*b*) change in relation of material costs to labor costs, as the size changes? (Reference, Goudriaan's paper.)

7 What should be the choice as to exact values for the numbers in the geometric series as against the rounded figures 10, 16, 25, 40, etc. in consideration of the fact that if exact sizes are kept there may be a tendency toward their displacement by gage numbers or roughly approximate numbers adopted for the sake of brevity of expression? (As is now the case with pipe sizes.)

8 Will the use of rounded values favor or hinder the correlation of metric and inch preferred-number dimensions (1 inch being approximately 25 mm., both of which are preferred numbers)?

9 Should calculated dimensions be rounded on drawings to preferred numbers when such dimensions are sufficiently independent in character as not to affect other essential dimensions? that is, when there is no objection from the point of view of involving other factors, is it desirable to round off dimensions in ordinary design work to preferred numbers?

10 What consideration should be given to series built up on roots of 2 and 3, as has been proposed at times, having in mind that such series do not repeat in successive orders of magnitude, and also that certain numbers in such series are coincident with series based on roots of 10?

11 What should be the scheme of the basic series of the form $\sqrt[n]{10}$ assuming that a 10 basis is necessary in order to adapt the system to our system of numeration? Should n be

(*a*)	80		40		20		10	5	
(*b*)		60		30	20	15	10	5,	or a combination
(*c*)	80	60	40	30	20	15	10	5?	

NOTE: (*a*) is the German and French proposal; (*b*) has the advantage of providing less than a 2-to-1 increase in the number of terms, at some points, from one series to the next; and (*c*), and to some extent (*b*), provides so many different numbers that it may be felt that the mnemonic feature would be lost. In the case of (*c*), would there be so many numbers that there would be no evident simplification over present practice? (Ref., discussion by Tuckerman in Hirshfeld-Berry paper (page 38) and subsequent letters.)

12 If a separate series is necessary for lengths of objects which are determined by the sum of related objects (such as the opening of a clamp or the length of a bolt), should such series be also on a geometric basis, or will it partake of arithmetical characteristics?

13 What general suggestions can be laid down as to the formation of series by skipping terms in an established series?

14 What, if any, should be the relation of preferred numbers to existing series, such as the Brown & Sharpe wire-gage system, (Ref., Paper by Hommel which appeared in the December, 1924, issue of the *Electrical Record*, and W. A. Del Mar's discussion of the Hirshfeld-Berry paper.), the common binary subdivisions of the inch, foot, and pound, such as 12, 6, 3, $1\frac{1}{2}$, $\frac{3}{4}$, $\frac{3}{8}$, etc., 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, 16, 8, 4, 2, 1, $\frac{1}{2}$, (oz.) etc.? (The decimal equivalents of the latter numbers fit the existing French and German series.)

15 What should be the relation of preferred-number sizes to the series which already tend to approximate geometric series, due to the setting up of parabolic arrays of sizes such as that shown on page 12 of the Hirshfeld-Berry paper?

16 What are the existing engineering and scientific applications of (*a*) geometric series, (*b*) particluar geometric series closely approximating one of the existing preferred-numbers systems? (Possible subject for thesis, or work by graduate student, affording a good opportunity for correlation of engineering experience with psychophysical law.)

These topics cover, though not completely, the major questions that have to be settled in the selection or development of preferred-numbers systems, and it is the intention that the definite recommendations of the Working Committee on each of these points will enable the general Preferred Numbers Committee, consisting of 22 representatives from 20 engineering and technical organizations, to arrive promptly at conclusions which can be put before American industry as the best means to make available this very important tool for standardization. The committee, in its studies, will make use of a very considerable volume of material which has been collected by the American Engineering Standards

Committee regarding the theory and applications of the system abroad. There are already a considerable number, possibly 100, of European standards, mainly German and French, in which preferred numbers have been applied. Even in American engineering and scientific work there are a surprising number of cases (apertures of photographic lenses, for instance) where geometric series at least have found application in size standardization, and a few of these series coincide in part with the European numbers.

Correspondence

CONTRIBUTIONS to the Correspondence Department of "Mechanical Engineering" are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on articles or policies of the Society in Research and Standardization.

Indicating Weights of Castings on Blueprints

TO THE EDITOR:

Mr. Durban's suggestion in the January number of MECHANICAL ENGINEERING—that of putting casting weights on drawings—is worthy of wide adoption.

The work of computation is less at the source than anywhere else; often this weight has been calculated for other purposes and it would entail no extra labor to add it to drawings. In one case a shop was making a line of castings in various sizes, the only difference being in the area; in the plant it was known that 50 lb. per sq. ft. was the standard weight for these castings, but the foundries who had the patterns sent to them did not know this until they had made castings or checked up themselves, and it would have been the simplest thing in the world to have given this weight.

In a small foundry the weight of a casting may have a great deal to do with the price. Should it be enough to pay for the initial expense of the cupola charge—"it's that first bed of coke that eats up the money," is a frequently heard expression—and constitute a third or a half of the total weight poured, the chances are that the foundryman will make a better price than if it be a casting of half that same weight. And in the small foundry the boss or the foreman is usually too busy or too dirty to spend the time necessary to compute weights; but tell him that the casting will weigh a ton and you wil! see his face brighten with relief and the prospect of a profitable charge.

The writer follows the practice of putting casting weights on everything which has a pattern number on it: thus, on a general drawing, a part may be noted as "PATT. KG-42, Wt. 127 lb." Not only does this serve as data for whatever purpose such may be required, but it is a check on casting weights as delivered to the shop. Quite recently this information was valuable on some initial deliveries that were 20 per cent overweight, and would have run into several tons.

DONALD A. HAMPSON.[1]

Middletown, N. Y.

The Need for Cheaper Hardness Tests[2]

TO THE EDITOR:

As service conditions become more severe and the cost of material increases, it is necessary to use every practicable method of improving the quality of material by eliminating that which is unfit for service.

There are a number of ways of doing this, most of which are comparatively expensive. Of course, reliance can be placed on conscientious manufacturers, provided they know just what material will prove satisfactory.

Chemical analysis and physical tests will also show the quality of a heat of steel, for example, but if enough tests are made on pieces furnished ready for service to insure satisfactory quality in the remainder, the cost is prohibitive.

Hardness tests are in general a good measure of quality, if enough experimental work is done to find the relation between the hardness and the other necessary properties as, for instance, the tensile strength. Usually the hardness test can be made without rendering the piece unusable.

To illustrate, it has been found that automobile axles having a certain hardness number stand up satisfactorily when put into cars. This measure of quality can then be applied cheaply to all the axles manufactured with a reasonable certainty that those which have the required hardness will give satisfactory service.

At all events, axles showing a satisfactory hardness are more valuable, commercially, than those which have not been tested. See the automobile advertisements illustrating parts of a car which show the impression made by a Brinell ball, and the text calling attention to this visual evidence that each part has been tested. Presumably, any part which reaches the customer has complied with rigid hardness requirements.

At present, the cost of making hardness tests is prohibitive except for pieces the failure of which would endanger life or limb. It is ordinarily used, therefore, only on munitions and parts for automobiles and aircraft. The reason for the high cost of measuring hardness is not difficult to find, if we consider the methods employed.

In the Brinell test, which is perhaps the most reliable and very widely used, the diameter of the impression is measured by means of a micrometer microscope—a tedious and trying operation, if many pieces are to be tested—and some shops make 5000 Brinell tests each day. If an image of the impression magnified many times could be projected on a ground-glass screen having a suitable scale, the measurements would be more easily made. A careful study of methods of handling the specimens when doing the work in this way would probably result in a considerable saving in cost.

The depth of the Brinell impression has of course been measured easily and quickly by apparatus attached to the ball holder, but Brinell numbers obtained in this way do not agree with those obtained from diameter measurements. At least, this device, which undoubtedly reduces the cost, has not come into general use.

The diameter of the Brinell impression is so large that it is not practicable to use it on accurately finished pieces.

The cost of making scleroscope tests is low because the number is read directly from a legible scale and the time required to make the test is very short. The scleroscope impression is so small that this method can be used on almost any piece. The scleroscope is often used on thin pieces such as clock springs, for which the Brinell method is unsuitable.

The reason that the scleroscope is not more generally used is that difficulty has been found in obtaining consistent values by different observers. Apparently this method has limitations which will make it unsuitable to be regarded by scientists and engineers, generally, as the method of the future for hardness testing.

In the past few years the Rockwell machine has been used extensively. Like the scleroscope, the impression in the piece is small and it can be used on thin pieces. Very hard steels, which flatten the Brinell ball, can be tested on the Rockwell machine by using the diamond point. As the Rockwell number is read directly from a dial at the time the impression is made, the cost is low.

If a hardness test for quality could be used on practically every piece of metal put into service, there would be several advantages. First, the uniformity of the material could be controlled and fabrication processes speeded up. For example: An automatic screw machine must be operated at speeds and feeds suitable for the hardest material. If each bar passed a hardness test to determine its cutting properties and the hard bars were removed, the screw machine could be operated at higher speeds and heavier feeds.

[1] M. E., Morgans & Wilcox Mfg. Co. Mem. A.S.M.E.

[2] Published with the approval of the Director of the Bureau of Standards.

Second, the allowable stress which can be used in designing a structure is obviously limited by the strength of weakest pieces. Could not a hardness test on each piece of structural steel, for example, be used to eliminate the weaker material and the working stress be increased? This would in turn reduce the amount of material required, with a corresponding reduction in cost.

In part these advantages can be obtained by using the hardness tests available now, but a practicable method of measuring quality (or hardness) at a cost which will not greatly increase the cost of the piece on which it is used will revolutionize the metal industries. Sometime this need will be filled by a machine which will function as efficiently and as continuously as our automatic screw machines. It may mark the quality number on each piece somewhat as we postmark letters. When that time comes the economic saving will benefit every one in a community which, like ours, depends upon mechanical equipment to supply most of its material needs, leaving us time for intellectual activities.

H. L. WHITTEMORE.[1]

Washington, D. C.

The Rotating Disk

TO THE EDITOR:

The following is a discussion of E. L. Thearle's paper entitled "The Rotating Disk," which appeared in the November, 1924, number of MECHANICAL ENGINEERING.

Previous writers on this subject (Föppl, Rankine, Stodola) have assumed that the disk is given an initial angular velocity ω and a torque applied to it just sufficient to maintain this velocity constant. Their solutions therefore permit us to examine the behavior of the disk at any given but constant speed, of which the most important is the speed at which the disk is to perform its service.

Mr. Thearle, on the other hand, proposes to determine the behavior of the disk if it is started from rest to its final speed, with the chief point of interest centered on the phenomena occurring while passing through the critical speed.

He correctly states that the expression "passing through the critical speed" suggests the presence of angular acceleration. This suggests that we have to deal with a problem of dynamics, and a solution thereof which does not involve even the simplest integration evokes the suspicion that something is amiss. To show that such is the case is not difficult.

The flexibility of the shaft is expressed by $F = Y/K$, wherein Y is the deflection, K a constant, and F the force with which it reacts against the deformation Y.

Now, if the author's formulas are correct, they should of course hold for any degree of flexibility of the shaft. Let us then consider the following two limiting cases, reference being made to the author's Figs. 4 and 5.

1 The shaft is perfectly rigid. Evidently for a rigid shaft there can be no deflection and hence we should have as a first condition $Y = 0$. Next, in the case of a rigid shaft, there will be plain rotation of the center of gravity of the disk around the axis O', with the constant eccentricity e, and since the system of axes of the author revolves with the body, this should be expressed by u = constant and v = constant; that is to say, by the fact that there is no change in the coördinates of the center of gravity of the disk with respect to the moving axes, no matter what the angular velocity and acceleration may be. Now let us see what answer the author's Equations [26] and [27] give.

We have a rigid shaft evidently when $K = 0$, since in this case the elastic reaction F becomes infinite for the least deflection Y. Substituting $K = 0$ in Equation [26] gives indeed correctly $Y = 0$. However, with $Y = 0$, Equation [27] becomes

$$\alpha u = \omega^2 v$$

showing that the coördinates of the center of gravity of the disk depend on the angular velocity ω and acceleration α.

This is contrary to the facts.

2 The shaft is infinitely flexible. This is the same as saying that there is no reaction of the shaft to any deformation, mathematically expressed by $K = \infty$. The disk in the present case behaves as if there is no shaft to constrain it in any way, and a torque applied to it causes simple rotation about the center of gravity, which itself remains at rest.

Thus the stationary center of gravity, when observed from a system of axes rotating around O', will describe a circle of constant radius, and this must be the answer of the author's formulas in the present example if they are correct.

Now with $K = \infty$, Equation [26] gives

$$0 = \omega^2(Y + u) + \alpha v \quad \text{or} \quad \frac{Y + u}{v} = -\frac{\alpha}{\omega^2}$$

and Equation [27] remains unchanged, giving

$$\frac{Y + u}{v} = \frac{\omega^2}{\alpha}$$

Thus, in the example, the author's formulas give a negative and a positive value, both also different as to magnitude for one and the same quantity $(Y + u)/v$. This is in itself inconsistent and far from expressing that the center of gravity describes a circle around O.

Thus again we have disagreement with the facts.

The two examples above show conclusively that an error has been committed chiefly due to the failure of the author to note that by his adoption of rotating reference axes the dynamics in the case

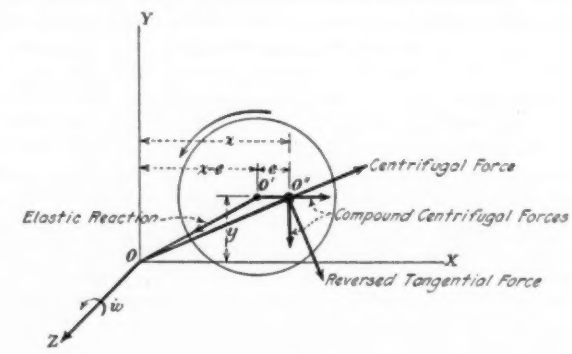


FIG. 1

become those of relative motion, which are necessarily different from the ordinary. It may therefore be of interest to conclude this discussion with the derivation of the equations of motion of the disk relative to a system of revolving axes.

The disk is accelerated from rest to full speed in a given manner by a couple, which as we know causes rotation about its center of gravity. If then a system of rotating axes be at all selected, it would seem obvious to have it revolve in the same direction and at the given angular velocity of the disk around its center of gravity. Thus, if the axis OX, at the time $t = 0$ when disk and axes are at rest, be selected to coincide with the eccentricity (line joining geometric center O' of the disk with its center of gravity O''), the said axis and eccentricity will remain mutually parallel during the entire motion as shown in Fig. 1.

Further, in Fig. 1, OZ is a vector at right angle to the XOY plane representing the rotation of the plane of reference when the angular velocity at the time $t = 0$ is ω. O is the intersection of the geometric axis of rotation (line joining the center of the journals of the shaft with XOY, O' the geometric center of the disk and also the center of the shaft portion to which the disk is fastened. OO' then is the deflection of the shaft and $O'O''$ the eccentricity e, which here always remains parallel to OX. Thus the coördinates of the center of gravity of the disk at the time t being x and y, those of its geometric center O' will be $x-e$ and y.

The actual forces are the couple T, which brings the disk up to speed, and the elastic reaction of the shaft

$$F = \overline{OO'}/K$$

K being the deflection in feet caused by a force of 1 lb.

Now, since the equations of motion are to be determined relative to the axes XOY which have at the time t the angular velocity ω, we have to add (see Routh, Dynamics of Rigid Bodies, vol. 2, sec. 26):

[1] Mechanical Engineer, Bureau of Standards. Mem. A.S.M.E.

1 Forces equal and opposite to those which the center of gravity of the disk would experience if it were fixed on the rotating XOY plane, i.e.,

Tangential force: $m\ \overline{OO''}d\omega/dt$ and

Centrifugal force: $m\ \overline{OO''}\omega^2$

2 The compound centrifugal forces (also called the forces of Coriolis);

$2m\omega dx/dt$ parallel to OY
$2m\omega dy/dt$ parallel to OX

These forces are shown in their proper direction in Fig. 1. Resolving them in directions parallel to OX and OY we have:

Force	Component along OX	Component along OY
Centrifugal.........	$m\omega^2 x$	$m\omega^2 y$
Reversed tangential.	$myd\omega/dt$	$-mxd\omega/dt$
Compound centrifugal	$2m\omega dy/dt$	$-2m\omega dx/dt$
Elastic reaction.....	$-(x-e)/K$	$-y/K$
Couple T...........	0	0

Hence the equations of motion are

$$m\frac{d^2x}{dt^2} = m\omega^2 x + my\frac{d\omega}{dt} + 2m\omega\frac{dy}{dt} - \frac{x-e}{K}$$

$$m\frac{d^2y}{dt^2} = m\omega^2 y - mx\frac{d\omega}{dt} - 2m\omega\frac{dx}{dt} - \frac{y}{K}$$

in which ω is a given function of the time.

These, and not the author's Equations [26] and [27] are the fundamental equations of the problem.

F. HYMANS.[1]

New York, N. Y.

TO THE EDITOR:

It is stated in Mr. Thearle's paper on page 671 of the November, 1924, issue of MECHANICAL ENGINEERING that the disk is assumed to possess pure rotation about the fixed axis O'. The inertia forces on the element ΔW are calculated on this assumption, with Y and θ considered constant in writing down the equations. Now it is found that Y and θ change with ω, and as ω changes with time, Y and θ change with time. This means that the expressions for the inertia forces introduced by the author are incomplete. The only ground on which the effects of the accelerations of Y and θ on the inertia forces might be neglected would be that these accelerations are of a much smaller order of magnitude than the accelerations $\rho\omega^2$ and $\rho\alpha$. But on examining the results given in Fig. 7, we find that the change of Y with time gives an acceleration of a much higher value than $\rho\alpha$. Therefore the inertia effects caused by changes in Y and θ must *not* be neglected. Therefore all of the author's calculations become erroneous.

D. DRESDEN.

The Hague, Holland.

[1] M. E and E. E., Otis Elevator Co. Mem. A.S.M.E.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relatioe to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING.

Below are given interpretations of the Committee in Cases Nos. 461, and 472–476 inclusive, as formulated at the meeting of December 1, 1924, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

CASE NO. 461

Inquiry: Is it intended that cast iron be not permitted for fittings referred to in Par. P-299 where the pressure exceeds 160 lb.? Is it intended that for all pressures not over 160 lb. extra-heavy fittings should be used if located below the water line? May cast iron fittings described in Table A-5 be used for steam fittings for pressures up to 160 lb. under the provisions of Par. P-299, or was it intended that Table A-6 should be used for pressures over 125 lb. and not exceeding 160 lb.?

Reply: There is a conflict between the second section of Par. P-299 and Par. P-12, and it is the opinion of the Committee that Par. P-12 should govern.

CASE NO. 472

(In the hands of the Committee)

CASE NO. 473

(In the hands of the Committee)

CASE NO. 474

Inquiry: Is it the intent of the Boiler Code that reports of tests on test specimens of steel castings of Class B grade for percentage of elongation and reduction of area, shall be reported as calculated by the formulas as prescribed in Par. S-55, or shall they be reported as calculations may determine from readings taken from the test specimen, and are these reports then to be checked against by the formulas above cited?

Reply: It is the opinion of the Committee that the percentage of elongation and the reduction of area should be reported as obtained from actual test results. These actual figures should then be checked against the two formulas obtained by using the actual tensile strength obtained from the test and the actual elongation and reduction of area should not be less than that obtained from the formula. In no case should the actual elongation and reduction in area be less than the minimum figure given in Par. S-55.

CASE NO. 475

Inquiry: It is contended that under the conditions that are obtained in hot water heating installations, it is impossible to attain a temperature of the boiler in excess of 250 deg. fahr., which is the limit specified in Par. H-58 of the Low-Pressure Heating Boiler Section of the Code, and where the relief valve is set at a pressure well within the safe limits of the boiler, the safety of the installation is not jeopardized. Therefore, is it not permissible in an open hot water heating system to omit the requirement of Par. H-58?

Reply: It is the opinion of the Committee that although a hot-water heating system may be installed initially as an open system, it may become "closed" by the action of corrosion or other accidental obstruction, and that the requirement of Par. H-58 is essential for safety.

CASE NO. 476

Inquiry: Is the reference in the last sentence of Par. P-230*b* to Par. P-212*b* "for the size of the staybolts, rivets or bolts" correct? Par. P-212*b* does not seem to apply.

Reply: It is the opinion of the Committee that this reference is a typographical error and should refer to Par. P-212*d*.

The Panama Canal Commission ordered from the Nordberg Manufacturing Co. a set of Diesel engines and generators of size and type somewhat unusual in this country. This Diesel plant will consist of three Nordberg Diesel engines of 3750 b.hp. each, the engine being of the two cycle, single-acting type with six cylinders, 29 in. bore and 44 in. stroke, running at 125 r.p.m. Each engine will be direct connected to a 3125 kva. generator of the flywheel type, three phase, 25 cycle, 2200 volt. These engines are the largest stationary Diesels that have ever been attempted in this country.

MECHANICAL ENGINEERING

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Meetings of A.S.M.E. Local Sections

THE Cleveland and Chicago Sections of The American Society of Mechanical Engineers held excellent meetings during January which are reported in this issue of Mechanical Engineering. The Cleveland Section, coöperating with the Cleveland Engineering Society and the Local Chapter of the American Society of Heating and Ventilating Engineers, arranged a program which treated comprehensively the problems of preparing and burning pulverized fuels. The Chicago Section held its second annual power meeting with a diverse program lasting two days. Both meetings were highly successful in that they were well attended, many engineers coming from distant points, the papers were well prepared, the discussion was thorough, and the arrangements for the meeting were well planned.

The ideal arrangement of the technical programs of a technical society is the one that each year gives opportunity to every member of the society to prepare or hear and discuss a paper on the latest developments or the newest thought in the phase of technical work in which he is interested. In a society with widespread membership such as the A.S.M.E. the Local Sections must bear much of the burden in contributing to such an ideal program. The success of the Cleveland and Chicago meetings is an indication that the Local Sections are able to do their part. A little coördination between the Local Sections and coöperation with the Professional Divisions is the next step toward the fulfilment of the ideal program.

War Construction Engineers Vindicated

COMPLETE vindication came late in January to the seven members of the Committee on Emergency Construction of the War Industries Board, indicted in December, 1922, for conspiracy to defraud the Government through control of the construction program during the late war, when Attorney-General Harlan Stone decided to abandon the prosecution of the case. Through this decisive step the Attorney-General repudiated the action of his predecessor in office who had attempted to brand a group of honest men as guilty of a most heinous crime, conspiracy to defraud the Government in time of war.

The men under indictment were: Benedict Crowell, Cleveland, former Assistant Secretary of War; William A. Starrett, New York; C. W. Lundoff, Cleveland; Morton C. Tuttle, Boston; John H. McGibbons, Chicago; Clair Foster, New York; and James A. Mears, New York. They included prominent and long-honored members of the engineering profession. When it became apparent in the spring of 1923 that court action on the charges against them was lagging, the Council of The American Society of Mechanical Engineers was one of many engineering organizations which urged a prompt trial. On January 30, 1924, Justice A. A. Hoehling, in the Supreme Court of the District of Columbia, completely exonerated the men against whom the charge of conspiracy had been brought. Attorney-General Stone's action directed that an appeal from Justice Hoehling's decision be not prosecuted.

Thus the final step has been taken in the complete vindication of men who in such a short period of time put through the greatest construction program the world has ever seen. The charges which challenged their integrity and honesty of purpose were known to be false by men who were in a position to judge intelligently of their validity, but the shadow of an unjust suspicion was, nevertheless, cast. With vindication comes a renewed sense of the service which these men rendered to their country in time of emergency, and of shame that the machinery of our Government should have been so prostituted as to serve partisan ends.

The Life of John Sweet

THE American Society of Mechanical Engineers has been blessed by the interest and service of three individuals who bore the affectionate and reverent title of "Uncle John." First came "Uncle John" Sweet, whose ideals of professional service bore fruit in the founding of the A.S.M.E.; later came "Uncle John" Fritz of Bethlehem, whose fame has been perpetuated by the John Fritz Medal; and lastly there was "Uncle John" Brashear, who loved the stars. All of these men made a profound impression on the Society and the engineering profession. It is fortunate, therefore, that with the publication of the Life of John Edson Sweet, the first chapter of which appears as the leading article in this issue of Mechanical Engineering, the published records of the lives of these three great men are complete.

When John Fritz and John Brashear died they both left autobiographical notes, and the Society may take great pride in the effective part they played in making the stories of their lives available not only to the engineering profession but also to the general public. John Edson Sweet, however, left no autobiography; but the story of his life was indelibly written into the history of his time. It became the task of the Society, therefore, to find a biographer who not only knew the history of that period of engineering upon which John Sweet left his imprint, but one who also knew John Sweet himself. The choice of Albert W. Smith, Dean Emeritus of Mechanical Engineering of Sibley College since 1921, was indeed a happy one, for Dean Smith is a man of recognized technical and literary merit as well as a former student and close friend of John Sweet.

Dean Smith undertook his task as a biographer with a keen appreciation of his responsibilities and opportunities. The friendship of these two men, begun back in the early days when Albert Smith was a young engineering student at Cornell and John Sweet was just "Professor," had never been broken. To adequately and faithfully portray his former teacher and lifelong friend was a task requiring the highest effort, the sincerest devotion. He made that effort, gave that devotion; the result is a faithful portrayal of the character, personality and achievements of the remarkable man whose influence is thus increasingly extended into the future and over the lives of coming generations of engineers.

John Sweet's imprint has been left for all time on the history of early mechanical design. His contributions to science are recognized; his achievements with the high-speed engine secured for him the award of the John Fritz Medal, one of the highest honors of the engineering profession. But his lasting influence is upon the hearts and minds of the men who came in contact with him. His biography is a valuable addition to that part of engineering literature which records the high technical achievement of men who must always first be numbered among those "who loved their fellow men."

Cleveland Symposium Revealed Successful Use of Pulverized Fuel

INCREASING interest in the application of pulverized coal to power plants led to a joint meeting of the Cleveland Engineering Society, the Cleveland Section of The American Society of Heating and Ventilating Engineers, and The American Society of Mechanical Engineers in Cleveland, Ohio, January 13, 1925, at the Hotel Winton. The attendance of a large number of combustion engineers from all over the country attested to the timeliness of such a conference.

The morning session was held under the chairmanship of Theodore A. Weager.[1] The first paper presented, by Walter J. Kline,[2] was on the subject of District Steam Heating in Small Communities and Residential Sections.

The underlying idea in the centralization of the heating system in outlying districts was stated to be not only conservation of fuel but conservation of effort as the result of community coöperation. The fundamentals involved in the discussion of district steam heating, whether applied to a large city district or to a few buildings of an isolated group, were briefly mentioned by the author. The pioneer worker in this field, according to Mr. Kline, was Birdsill Holly, noted water-works engineer, who carried out his experiments in Lockport, N. Y., in the middle seventies of last century.

The paper was illustrated by lantern slides showing examples of construction of underground steam lines, both high-pressure and low-pressure. The material used, according to conditions, was heavy wrought iron or steel. All high-pressure pipes were electric- or oxy-acetylene-welded, as well as the larger sizes of low-pressure pipes.

The importance of pipe insulation and of soil drainage was emphasized. The elements entering into the calculation of the price at which the heating unit of 1000 lb. of steam must be sold were presented. It was stated that the form of district-steam-heating rates was usually that of a descending scale of unit prices and an ascending scale of pounds of steam used; these rates being given in a Bulletin published by the National District Heating Association. In conclusion the author stated that the district plant could supply heat units at a lower cost than that at which the individual consumer could produce them himself.

In the discussion which followed various questions as to structural details were asked and answered, following which H. M. Nobis (Cleveland) asked if the author had any records showing what the steam consumption was in various kinds and classes of dwellings. Mr. Kline answered that a great deal of information of that character was to be found in the handbook of the National District Heating Association, and that the Research Committee had assembled considerable information on the subject.

Prof. M. E. Vose[3] inquired regarding the losses along the line. The author stated that the figure of 5 per cent condensation loss which he had quoted was based upon the condensation per square foot of underground steam pipe per hour, and that it had been found to represent the maximum figure of heat loss in the main. As to the 85 per cent of steam produced, which according to the author was finally delivered to the consumer, this took into consideration an additional quantity of unaccounted-for losses amounting to 10 per cent. Possibly the greater part (5 to 8 per cent) of these would represent losses within the boiler room itself, depending on the type of equipment and the manner in which the plant was operated.

E. P. Roberts[4] emphasized the author's remarks on the uneconomical way in which most of the house-heating boilers were operated.

The meeting adjourned at noon and reconvened at 2:00 p. m. for the afternoon session, over which James H. Herron[5] presided. This session was devoted to equipment for pulverizing and handling fuels, and the first paper presented, by H. W. Brooks,[1] dealt with The Development of Pulverized Coal as a Boiler Fuel. This paper appeared in the February number of MECHANICAL ENGINEERING, p. 89. In the discussion that followed, C. W. E. Clarke[2] remarked that the author had omitted to mention in his brief historical review the installation at the Seattle Electric Company, in 1916 and 1917, of eleven 4000-sq. ft. Babcock boilers.

The next paper was one by Henry Kreisinger,[3] on The Central Pulverizing Plant and Its Operation, which was illustrated with lantern slides. An abridgment of Mr. Kreisinger's paper will appear in a later issue of MECHANICAL ENGINEERING. The author considered only the first stage of the process of converting pulverized coal into mechanical energy, namely, the problem of preparation, and dwelt particularly on the dust question and on driers for removing the moisture in coal.

After a few questions on Mr. Kreisinger's paper were answered, H. G. Barnhurst[4] presented a paper on the preparation of pulverized coal which was printed in the February issue of MECHANICAL ENGINEERING, p. 87. Lantern slides were used for illustration.

In the short discussion which followed, G. E. Chamberlain[5] asked if there was any loss in heating power due to drying, especially in the case of coal containing considerable quantities of volatile gases. The author answered that there formerly was, and that the drying temperature should be kept below the point at which the volatile gases were set free. Pyrometers would control the temperature of the gases passing through the driers.

Next in order on the program was a paper by W. W. Pettibone[6] dealing with The Unit Pulverizer. The author gave first a short classification of the present types of pulverizers according to speed (slow, medium, or high) or according to the method of pulverization (attrition or impact). He expressed his belief that the best results were obtainable on a high-speed unit pulverizer working on the impact principle, as it was much easier to crush a lump of coal by a blow from a light hammer than to crush it by application of weight or by a roller.

In the Aero pulverizer as now built, fifteen years of experience were said to be embodied. It worked on the principle of stage pulverization and stage separation of the finished product by induced air.

It was evident that the air velocity in each stage would sustain and carry particles of coal of a weight per unit area equivalent to or less than the head of the air current. By so proportioning the areas in the various stages that a definite relation existed between them, the resultant fineness of the delivered product would be entirely under the control of the operator through his regulation of the air admitted at the feed end of the pulverizer.

A thorough admixture of a large quantity of air with the pulverized coal prior to its admission to the furnace through the burner was obtainable. The author stated that with the Aero unit 75 per cent of air was generally admitted with the coal and only 25 per cent left out to be mixed inside the furnace, consequently the required furnace volume was reduced. He further stated that a recent improvement was the use of preheated air induced through the air-cooled side walls of the furnace and mixed with the fuel delivered to the burner.

The capacity of the unit machine could be varied from 20 to 125 per cent of its rated capacity by regulation of the feeder. The unit pulverizer was said to have successfully used fuel of

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[1] Mgr., Cleveland Office, Buffalo Forge Co. Mem. A.S.M.E.
[2] American District Steam Co., No. Tonawanda, N. Y. Mem. A.S.M.E.
[3] Case School of Applied Science, Cleveland, Ohio. Mem. A.S.M.E.
[4] Consulting Engineer and Statistician, Cleveland, Ohio. Mem. A.S.M.E.
[5] Past-President, The Cleveland Engineering Society. Mem. A.S.M.E.

[1] Fuel Engr., Pittsburgh Experiment Station, U. S. Bureau of Mines. Mem. A.S.M.E.
[2] Engrg. & Constr., Dwight P. Robinson & Co., New York, N. Y. Mem. A.S.M.E.
[3] Research Engr., Combustion Engrg. Corp., New York, N. Y. Mem. A.S.M.E.
[4] Advisory Engr., Fuller-Lehigh Co., Fullerton, Pa. Mem. A.S.M.E.
[5] Decatur, Ill.
[6] Chief Engr., Aero Pulverizer Co., New York, N. Y.

unusually high moisture content. Power consumption under normal conditions of moisture in coal ranged from 12 to 17 kw-hr. per ton, depending on the physical characteristics and moisture.

One of the advantages of the unit system was claimed to be its freedom from dust, as the only point at which the fuel was under pressure above atmospheric was in the delivery pipe from the unit to the burner, a part easily made and maintained dust-tight.

The author summed up his presentation by stating that the unit pulverizer pointed to low initial cost, low operating cost, reliability of operation, flexibility of control, cleanliness in operation, and simplicity in installation.

After the paper was read the author was asked how small a boiler could be equipped with the system described and give practical results, to which he answered that his company had made installations for boilers ranging from 150 to 1000 hp.

The next paper to be presented on this subject was one by Gould Coutant,[1] which appears on page 183 of this issue. The paper was read by R. D. Rogers and illustrated by lantern slides.

The meeting adjourned at 5:30 p.m. and after an informal dinner reconvened for the evening session at 8 p.m., under the chairmanship of Ervin G. Bailey.[2] This session was devoted to the design and operation of plants burning pulverized fuel.

The first speaker was John Wolff,[3] whose paper on burning pulverized fuel in large boilers, with results obtained in recent tests, will appear in abridged form in an early issue of Mechanical Engineering.

The tests Mr. Wolff discussed were conducted at the Lake Shore Station, using the regular plant supply of coal. The records showed that the net operating efficiency for the installation was from, July to November, inclusive, about 88 per cent, the gross efficiency being about 90 per cent.

The next speaker, P. W. Thompson,[4] presented a paper on some design features and operation experience in connection with the Detroit-Edison Trenton Channel plant, an abridgment of which will be published shortly in Mechanical Engineering. The presentation was freely illustrated by lantern slides.

Mr. Thompson remarked that the Trenton Channel plant had been started with very little difficulty and that no serious troubles developed later. It has been in operation for over six months, long enough, he thought, to show that the choice of pulverized fuel for the plant was correct.

E. H. Tenney,[5] who followed, presented a paper dealing with some features of design and operating experience in the utilization of low-grade fuel at the Cahokia station of the United Electric Light & Power Co., and also made use of lantern slides in his presentation.

The present generating capacity of the plant, he stated, was 150,000 kw. with two sections out of four, when completed, in operation. The coal used contained about 16 per cent ash, which was high in sulphur and in iron content and had a fusion point about 2000 deg. fahr. A noticeable feature about the boiler plant was the absence of economizers. This was due to its nearness to the mines, making the coal price low enough not to justify such an installation.

In connection with the kilowatt-hours used per ton of coal, Mr. Tenney presented a tabulation showing that the driers took for their fans 2.66 kw-hr. per ton, pulverizing, 16.15 kw-hr., and air compressors, 8.52 kw-hr. The cost of handling and preparation, including maintenance of all coal preparation equipment, was stated to be 36 cents per ton.

The next speaker was John Anderson,[6] who presented the results obtained to date at the Lakeside plant, Milwaukee, Wis. Mr. Anderson stated that his part of the evening's program was confined to the submission of data bearing on costs gathered by his company during its four years of operation with pulverized fuel. As the figures included a number of expenses incurred in the development stages, some corrections were necessary if present-day costs were desired. The figures for the month of December, 1924, given below were unit costs in cents per switchboard kw-hr., net.

A	Total material	0.012
B	Total labor	0.049
C	Cost of fuel	0.261
D	Total cost of production	0.322

The total-labor figure was here based on an average labor rate per man-hour of 75 cents. The cost-of-fuel figure was based on a cost of $16 per 100 million B.t.u. as received, f.o.b. car-dumper hopper.

Item A might be subdivided into two parts:

1	Maintenance material	0.006
2	Operating material	0.006

The first of these items covered all material required in maintaining every piece of equipment in the station from the car dumper to the switchboard. The second item covered lubrication, packing and all other corresponding operating material.

Item B might also be subdivided into two parts:

1	Maintenance labor	0.016
2	Operating labor	0.033

The first of these items covered all labor required to maintain the entire equipment in the station from the car-dumper hopper to the switchboard. The second item covered coal and ash handling, operating labor in the pulverizing house, the boiler and turbine room, the switchboard, and, in short, all the operating labor from the car-dumper hopper to the switchboard.

Combining items A and B would give:

1	Total maintenance cost	0.022
2	Total operating cost	0.039

Item C covered the cost of coal, f.o.b. car dumper. Any additional labor or material required in the handling of coal was charged direct to the station in the form of an operating or maintenance expense.

Item D was the sum of items A, B, and C; it covered all operating and maintenance cost from the car-dumper hopper to the switchboard, including the cost of fuel.

A curve showing the variation of B.t.u. per switchboard kw-hr. net, at the Lakeside station, for the period from March, 1921 to December, 1924, might be roughly summarized by the following figures:

Year	B.t.u. per Switchboard Kw-hr.
1921	approx. from 21,000 to 19,000
1922	approx. from 19,000 to 18,000
1923	average of about 18,000
1924	approx. from 18,000 to 16,000

The figures for the last six months of 1924 were as follows:

Months, 1924	B.t.u. per Switchboard Kw-hr.
July	17,700
Aug.	17,200
Sept.	16,200
Oct.	16,600
Nov.	16,000
Dec.	16,200

The lowest point of the curve, for the middle of October, gave 15,800 B.t.u. per switchboard kilowatt-hour.

G. G. Bell[1] opened the general discussion on powdered-fuel-fired furnaces after the four papers scheduled had been presented. He spoke about tests his company had made on various boilers in the Springdale station. The gross efficiency was stated to be corrected by the power consumption of the auxiliaries, and a second correction was applied on account of the variation in the superheat. The curves which he presented were based on normal conditions in the older end of the plant, with a pressure of 300 lb. and a superheat of 200 deg. fahr.

The average of the efficiencies obtained by five stoker-fired boilers from June to December, 1924, was stated to be 75.4 per cent, the average boiler rating for the period being 228 per cent,

[1] Chief Engr., Furnace Engineering Co., New York, N. Y.
[2] Pres., Bailey Meter Co.; Chairman Cleveland Section, A.S.M.E.
[3] Chief Engr., Cleveland Electric Illuminating Co., Cleveland, Ohio. Mem. A.S.M.E.
[4] Chief Asst. Engr. of Power Plants, Detroit Edison Co., Detroit, Mich. Mem. A.S.M.E.
[5] Chief Engr. of Power Plants, Union Electric Light & Power Co., St. Louis, Mo. Mem. A.S.M.E.
[6] Chief Engr. of Power Plants, Milwaukee Elec. Ry. & Light Co., Milwaukee, Wis. Mem. A.S.M.E.

[1] Mgr., Power Development, West Penn Power Co., Pittsburgh, Pa.

whereas for the same period the efficiency of the boiler fired with the Lopulco system of powdered fuel averaged 78.6 per cent, with an average rating of 272 per cent.

Some trouble had been experienced due to the transmission air coming in contact with the cold coal-bunker walls and chilling the moisture, thus making the powdered coal soggy and preventing the feeders from working properly.

The powdered ash collected quickly on the tubes, and it had been found necessary to remove it at regular intervals. Practically no trouble had been experienced from slag with the powdered-fuel boiler. The experience with water-cooled side walls was stated to have been satisfactory, no trouble whatsoever having taken place with the tubes.

The maintenance cost of this boiler had been about 18 cents per ton during the last year, or somewhat higher than on the old stoker-fired boilers during the same period; however, the latter had been operated at lower ratings, and experience so far would indicate that the maintenance cost was about equal. With the type of coal which was being burned some method of cooling the ash was necessary, and this must take place close to the stoker.

From experience to date with these boilers the indications as summarized by Mr. Bell were:

1 Better efficiency could be maintained with the powdered-fuel boiler.

2 The loss in carbon in the ash did not amount to over 1 per cent, as compared to 3 or 4 per cent of the heat value of the fuel being lost in the stokers.

3 By giving the boiler proper attention the powdered-coal boiler would operate with $13^1/_2$ to 14 per cent CO_2 at exit, as compared with 12 per cent with stokers.

4 The powdered-fuel boiler could be operated at a considerably higher rating and still maintain the same net efficiency, thereby reducing the carrying charges per unit of output.

5 The boiler could be maintained in a clean operating condition easier and its availability was higher.

6 On the whole, the operating department at the Springdale station preferred to operate the powdered-fuel boiler.

C. W. E. Clarke[1] mentioned that in 1923 it had been decided to change the Colfax station to pulverized fuel and that the company had never regretted it, although there had been some major and minor difficulties, as, for instance, some serious erosions on side walls. Two furnaces were now operating and three additional were now going in. They were to be equipped with fin-tube-type walls, with the expectation that this would eliminate any difficulty of furnace maintenance from the cause mentioned.

Mr. Clarke stated also that the boiler in the Allegheny County steam heating plant, utilizing pulverized fuel, had been in operation its second winter, and that while there had been a few minor difficulties, in general the success had been all that could be expected.

J. W. Parker[2] stated that in approaching the consideration of the pulverized fuel his company came rather with the attitude of the critical user than of the enthusiastic pioneer. The Trenton Channel plant had not operated more than a very few weeks before it became evident that pulverized fuel would be a success from an operating standpoint.

J. C. Hobbs[3] stated that the whole problem could be resolved into, first, the generation of heat, and then bringing it to a condition where it could be the most efficiently absorbed. On the generation end he was strongly in favor of maintaining high furnace temperatures and employing water-cooled refractories, the tubes being fully embedded.

The speaker called attention to the advantage gained from pulverized fuel in the way of increased boiler capacity with high draft conditions.

W. E. Caldwell,[4] who next discussed the paper, showed some slides on the Sherman Creek station with Murray fin-wall water-cooled furnace. This station was built in 1913 and contained 44 stoker-fired boilers. Later six additional powdered-fuel boilers of various types had been installed in an experimental way. The first boiler had a Fuller equipment, with three triplex feeders feeding into the nine burners in the front of the boiler. The second boiler in the row originally had Quigley feeders and burners which had been replaced by Fuller feeders and burners for good reasons. The third boiler had what was known as a Ripley multimat burner. There were two feeders and two burners. It was a type in which 100 per cent of the air was united with the coal before admitting it to the furnace. The next one was the pot-type furnace to which illusion had been made by Mr. Barnhurst. The fifth boiler had been originally provided with the Raymond mill feeding into a Bergman burner as an independent unit; it had been replaced by two impact pulverizers. The last boiler was fired by the Furnace Engineering Company's Simplex pulverizer to which reference had been also made in the afternoon. This pulverizer had operated continuously for 350 hr., and the boiler had been taken out for cleaning and placed in service without any work being done on the pulverizer and was still in service up to the time Mr. Caldwell left.

[1] Engrg. & Constr., Dwight P. Robinson & Co., New York, N. Y. Mem. A.S.M.E.

[2] Ch. Engr., The Detroit Edison Co., Detroit, Mich. Mem. A.S.M.E.

[3] Formerly of Duquesne Light Co.; now of Diamond Alkali Co., Painesville, Ohio. Mem. A.S.M.E.

[4] Asst. to Genl. Supt., Power Plants, The United Elec. Light & Power Co., New York. Mem. A.S.M.E.

J. G. Worker[1] said that for the past few years the sale of stokers had been following very closely the sale of water-tube boilers. He did not think that the development of pulverized coal was going to come from a lessening in the installation of stokers.

Mr. Baker[2] called attention to the fact that there had been no discussion as to the cost of maintenance and operation of the unit type. Replying to him, Mr. Rogers, of the Furnace Engineering Co., said that there was no maintenance whatever for the first 2000 tons pulverized per machine, and that thereafter the cost would not exceed three cents a ton pulverized. Mr. Pettibone, of the Aero Pulverizer Co., said that his company had records showing maintenance to be under three cents per ton of coal pulverized over periods running from six to nine months.

The Second Annual Power Meeting at Chicago

APPROXIMATELY three hundred and fifty engineers were registered at the Second Annual Power Meeting of the Chicago Section of The American Society of Mechanical Engineers held at the Hotel La Salle on Wednesday and Thursday, January 14 and 15, 1925. The program consisted of a dinner, three excellent technical sessions, and an interesting inspection trip. The quality of the papers and the completeness of the discussion made a highly successful gathering.

The feature event was the dinner on Wednesday evening at which James D. Cunningham, Chairman of the Chicago Section, presided. The principal speaker was David R. Forgan, vice-chairman of the Board of Directors of the National Bank of the Republic, who discussed War and Credit. He was followed by Frank D. Chase who emphasized the importance of the Power Problem of Modern Industry.

Technical sessions were held on the morning and afternoon of the fourteenth and on the morning of the fifteenth. Seven papers were presented. James D. Cunningham presided at the session on Wednesday morning, at which T. A. Peebles discussed Combustion Control and H. D. Savage presented a paper on the Water-Cooled Furnace. Both of these papers with a record of the discussion appear in this issue of MECHANICAL ENGINEERING.

The desirability of a national code to cover steam and water piping was presented for discussion, but because of lack of time it was voted to have a committee of the Section review the matter and make a report.

Professor H. S. Philbrick, past-chairman of the Chicago Section, presided at the afternoon session, at which three papers were presented. Robert Cramer compared the Uniflow and the Compound Counterflow Engine. Francis Hodgkinson discussed Modern Steam Turbines and L. H. Morrison took up the Diesel Engine. The papers by Messrs. Cramer and Hodgkinson appear in abridged form with the discussion in this issue of MECHANICAL ENGINEERING. Mr. Morrison's paper with an account of the discussion will appear in the April issue.

The session on Thursday morning was presided over by W. L.

[1] Asst. to Pres., American Engrg. Co., Philadelphia, Pa. Mem. A.S.M.E.

[2] Ohio Public Service.

Abbott. C. W. E. Clarke presented a paper on Air Preheaters and G. G. Bell gave one on Turbine- and Boiler-Room Auxiliaries. Both of these papers appear with the discussion in this issue. At the close of the session Mr. Abbott described the outstanding features of the Crawford Avenue Station of the Commonwealth Edison Company which was visited in the afternoon. This inspection trip proved of great interest as there were many novel features, including three large turbines built by different manufacturers and embodying the latest developments in turbine work, special reheating boilers, and novel coal-handling and auxiliary equipment.

Oil and Gas Power Week

"THE end of petroleum and gasoline as we know them is actually imminent, and whatever may be done to forestall it, will not prevent its coming entirely.

"Of the best substitutes for gasoline for use in motors not essentially different from the present ones, none at present available can do more than delay the inevitable end for at most a few years."

Thus D. S. Killefer of the American Chemical Society focuses attention on the future fuel situation for automobiles. Engineers who design oil and gas engines for use in industries are equally concerned as to fuels that will be available in the future.

April 20 to 25 has been set aside for "Oil and Gas Power Week" and fifteen technical organizations will sponsor technical meetings throughout the country to bring the combined technical knowledge of the country to bear on the problem of conserving petroleum resources. These organizations are:

American Chemical Society, American Institute of Chemical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Marine Designers, American Society of Mechanical Engineers, American Society of Naval Engineers, American Society of Refrigerating Engineers, American Petroleum Institute, National Association of Stationary Engineers, National Safety Council, Society of Automotive Engineers, Society of Naval Architects and Marine Engineers, U. S. Bureau of Mines, U. S. Bureau of Standards, U. S. Geological Survey.

The possibilities of this movement are far-reaching. Already suggestions of problems for discussion have been made from all kinds of sources and covering every conceivable phase of oil and gas power.

The national committee in charge of all arrangements consists of W. F. Durand, President, A.S.M.E., Chairman; James F. Norris, President, A.C.S., J. Edgar Pew, President, A.P.I., C. E. Lucke, W. Trinks, L. H. Morrison, and W. E. Bullock, Secretary, 29 West 39th St., New York City.

The Rotor Ship's Trip to Scotland

THE rotor ship *Buckau*, which was described in the January issue of Mechanical Engineering, sailed from Danzig on February 5, 1925, bound through the Kiel Canal for Leith, Scotland, with a cargo of lumber, and arrived at its destination on the 17th. As this is the first cargo trip that this novel craft has undertaken it has been watched with a great deal of interest by European marine men.

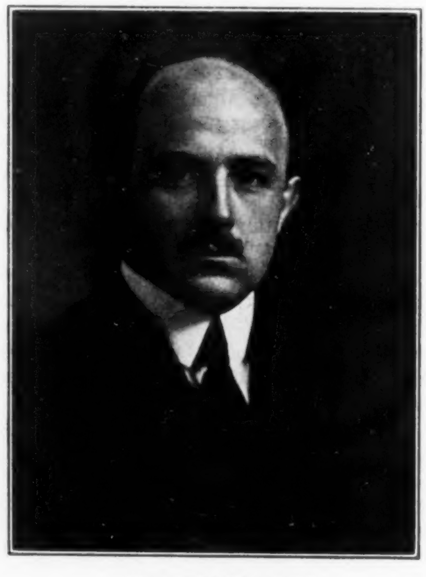
The *Buckau* is a ship of 600 tons on which are mounted two vertical rotors about nine feet in diameter and sixty feet high. These rotors are made to revolve at varying speeds and in both directions with the use of small quantities of power. Wind blowing on the revolving rotors impels the boat, much as a spinning baseball is deflected from its initial direction by the action of the air against it. This "Magnus effect," as it is called, was utilized by Flettner in constructing the rotor ship which enthusiasts look upon as an important means of reducing marine transportation costs and conserving fuel. This view is based on the small power needed to move the rotors and the small crew required to man a rotor ship as compared to a sailing vessel. The *Buckau* is a relatively small ship and an experiment on a larger scale will be necessary before the value of the method of propulsion employed can be firmly established.

The *Buckau* is equipped with a 160-hp. Diesel engine which is used to maneuver the ship in harbors. This auxiliary engine was called to service when fighting storms encountered in the Baltic.

Death of Roger M. Freeman

IN TEN years Roger Morse Freeman, who died suddenly of acute appendicitis on January 21, 1925, at 33 years of age, had accomplished more in engineering design and construction than most men find opportunity for in a lifetime. The cost of structures completed under his design and supervision in this short time aggregated more than $25,000,000. The end found him driving ahead on the design and construction of a 15,000-horsepower hydroelectric plant near Oakdale, on the Tippecanoe River in Indiana, with more than 500 men on a difficult rush job of winter construction.

Mr. Freeman was graduated from the Massachusetts Institute of Technology with a B.S. in Electrical Engineering in 1914. His studies at M. I. T. had been supplemented by a season at the great German engineering school in Charlottenburg where he specialized in internal-combustion engines. His engineering training began at the early age of 15 when he was a rodman in a surveyor's party for the New York Board of Water Supply. Next a college vacation was spent as assistant engineer in a construction camp back of the Sierras on the Los Angeles Aqueduct, and still another as a machinist in the marine-repair shops of the Atlantic Works in East Boston. Graduation from college was followed by a year and a half spent as assistant engineer for John R. Freeman on the design of large hydroelectric developments in the United States and Canada, and as assistant engineer for the Turner Construction Company on reinforced-concrete-building construction.



Roger M. Freeman

In January, 1916, Mr. Freeman became construction engineer for the Chase Rolling Mills and Waterbury Manufacturing Company of Waterbury, Conn., concerns then in the rush of war work. He designed and supervised the construction of several multi-story reinforced-concrete factory buildings so satisfactorily that when his employers decided to build a large machine shop for fabricating their own heavy machinery for working brass and copper tubes and plates, almost the only specifications given him were: "We need a machine shop about 400 feet by 100 feet. Make it the best of its size in New England."

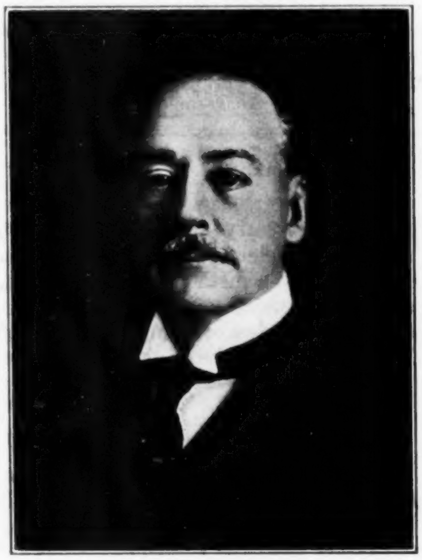
As this building neared completion Mr. Freeman was summoned into conference by the Secretary of the Navy and requested to visit a certain large steel works under construction and report on what was causing delay. The result of his report was that he was made supervising engineer in the Navy Department and put in charge of the completion of the plant. In six months, working three shifts through one of the worst winters of recent years, he had the plant ready to forge shafts and guns. His success in getting all hands to pull hard together was so marked that he was sent here and there to speed up construction wherever it lagged. As supervising engineer in the Navy Department Mr. Freeman's work included the design and construction of large steel plants for the Erie Forge and Steel Company, Erie, Pa., and the Pollack Steel Company, at Cincinnati; the gun-treatment plant at the Allis Chalmers Company, Milwaukee; dormitories for the General Electric Company at Erie; and the design and construction of the U. S. Navy armor-plate and gun-forging Plant at South Charleston, West Virginia. It poured its first heats a short time previous to the Disarmament Conference, since which it has stood idle.

Mr. Freeman had hoped to continue in metallurgical structural lines but, no openings being found in the depressed conditions of this industry following the war, he turned back to hydroelectric construction in which he had had experience after leaving college. Plans were under way for him to join forces with his father, John R. Freeman, at the time of his death.

He had been a member of the Society since before his graduation from college, and was also a member of the American Institute of Electrical Engineers, the American Society of Civil Engineers, and the American Association of Engineers.

William D. Hoxie, Vice-Chairman of the Babcock & Wilcox Co., Dies Suddenly

WILLIAM D. HOXIE, vice-chairman of the Babcock and Wilcox Company, died suddenly from heart trouble on January 12, 1925, on board the S.S. *Southern Cross* about three days north of Rio de Janeiro. He had started out on January 3 on an outing to South America, accompanied by his wife and niece.



WILLIAM D. HOXIE

Mr. Hoxie was born in Brooklyn on July 1, 1866, and received his early education in the public schools of that city. In 1889 he was graduated from Stevens Institute of Technology as a mechanical engineer. That same year he became connected with the Babcock and Wilcox Company and all his active life thereafter was spent in the service of that Company.

Early in his career Mr. Hoxie became connected with the marine department of Babcock and Wilcox and it was due largely to his energy and activity that installations of the Babcock and Wilcox boiler were made on board a number of merchant vessels.

In 1899 the first boilers designed by him were built for the U. S. S. *Alert*. This became the standard type of Babcock and Wilcox marine boiler, with the essential features of the drum in front, the increase of furnace volume towards the back of the boiler and the baffling at right angles to the tubes. With slight modifications and improvements this is still the standard.

Mr. Hoxie was an early advocate of the use of superheat. He had a superheater fitted to the boiler of his yacht and ran a great many experiments, including one series under the direction of naval engineers which for a long time gave more reliable and useful information about superheat than could be obtained elsewhere.

One demand from the Navy met by Mr. Hoxie was for a very light boiler which could only be secured by tubes of 1 in. in diameter. After studying all the designs on the market he decided that the White-Forster boiler was the best for this purpose. It had the special merit of the ability to withdraw and replace a single tube without disturbing any other. The first boilers built by his company of this type had lower drums with the tube sheet flattened in accordance with the original design. Experience showed that there were objections to this type and Mr. Hoxie developed a cylindrical lower drum which removed the objection. This involved slight changes elsewhere in the boiler to retain the desirable feature of the removability of tubes. More than five hundred boilers of this type have been supplied for the U. S. Navy.

Mr. Hoxie's abilities, which were not only as an engineer but as a negotiator as well, marked him for high executive positions. In 1897 he became vice-president of the Babcock and Wilcox Company. In 1919 he became president of the company and at the time of his death had been made vice-chairman of the Board of Directors. Although his principal attention was always devoted to the marine department he was constantly consulted on other engineering questions and matters of policy.

He was an ardent yachtsman and in recent years his yacht *Idalia* has been a center from which he dispensed princely hospitality to his many friends. He had fitted oil fuel to the boiler of this vessel and was enthusiastic about its success. He was a trustee of Stevens Institute of Technology, of Webb Institute of Naval Architecture and of the Wilcox Memorial Library in Westerly, R. I., a member of the Engineers, New York Yacht and Lawyers Clubs of New York City and of the Army and Navy Club of Washington, and a member of The American Society of Mechanical Engineers, the American Society of Naval Engineers, the Society of Naval Architects and Marine Engineers and the Chamber of Commerce of the State of New York.

(From an appreciation of Mr. Hoxie by ***W. M. McFarland****)*

U.E.S. Report for 1924

BELOW is a summary of the report of the treasurer of the United Engineering Society for the calendar year 1924. The officers of the U. E. S. for the coming year are: President, W. L. Saunders; First Vice-President, George H. Pegram; Second Vice-President, J. V. W. Reynders; Secretary, Alfred D. Flinn; Treasurer, Jacob S. Langthorn; Assistant Treasurer, Henry A. Lardner. *Finance Committee:* George H. Pegram, *Chairman*, J. Vipond Davies, W. F. M. Goss, Bancroft Gherardi, and the President, ex-officio.

The membership of the Board of Trustees for 1924 is as follows:

Representing the Civil Engineers: W. J. Wilgus; George H. Pegram; Lewis D. Rights.

Representing the Mechanical Engineers: W. L. Saunders; W. F. M. Goss; James H. Herron.

Representing the Mining Engineers: J. Vipond Davies; J. V. W. Reynders; Walter H. Aldridge.

Representing the Electrical Engineers: Bancroft Gherardi; Henry A. Lardner; H. H. Barnes, Jr.

SUMMARY

OPERATION OF BUILDING

Credit balance January 1, 1924		$ 8,070.94
Revenue from prior years		50.00
Building revenue, 1924	$114,932.65	
Building expenditures, 1924	97,248.95	17,683.70
		$ 25,804.64
Annual payment to Dep. & Renewal Fund.	12,000.00	
Additional payment to Dep. & Ren. Fund.	5,000.00	
Reserve for depreciation of capital of Engineering Societies Library	4,000.00	21,000.00
Credit balance Dec. 31, 1924		$ 4,804.64

OPERATION OF LIBRARY

Maintenance and recataloging revenue	$ 39,853.48	
Maintenance and recataloging expenditures	39,853.48	
Balance Dec. 31, 1924		$ 0.00
Service Bureau revenue	19,363.26	
Service Bureau expenditures	18,828.95	
Operating balance		$ 534.31
Previous credit balance		863.81
Credit balance Dec. 31, 1924		$ 1,398.12

FUNDS AND PROPERTY

Funds held by U.E.S. Dec. 31, 1924 (book value):	
Depreciation and Renewal	$175,269.29
Engineering Foundation	477,720.05
Library Endowment	96,047.00
General Reserve	10,000.00
John Fritz Medal (U. E. S. custodian)	3,500.00
Reserve for depreciation of capital of Library	4,000.00
Total	$ 766,536.34
Real estate owned by U.E.S., cost to Dec. 31, 1924	1,966,569.44
Operating cash and petty cash	10,504.59
Accounts receivable	2,141.97
Value of Library (as appraised for insurance)	329,000.00
Total property for which U.E.S. is trustee or custodian	$3,074,752.34

Book Reviews and Library Notes

THE Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Books Received in the Library

ALIGNMENT CHARTS FOR THE ENGINEER; Part 1, Air and Steam. By Stanley R. Cummings and Joseph Lipka. John Wiley & Sons, New York, 1924. Unbound in heavy envelope, 9 × 12 in., $2.25.

A collection of twenty alignment, or nomographic charts including the formulas relating to air and steam most frequently used in practice. These deal with the pressure, volume and temperature formulas of perfect gases, the discharge of air and steam through orifices, the flow of steam and with air compression. The charts are large enough in scale to give accurate results and will eliminate numerical computations.

COMBUSTION IN THE POWER PLANT. By Thomas A. Marsh. Combustion Publishing Corporation, and D. Van Nostrand Co., New York, 1924. Cloth, 5 × 8 in., 255 pp., diagrams, tables, $2.

In this book, an engineer of long experience in steam production gives information on the varieties of coal available in different parts of the United States and advice on the most efficient methods of burning them. Such practical problems as furnace design, stoker and boiler selection, draft and chimney design are discussed in plain, concise fashion. Questions of boiler-plant operation are also treated. The book should interest owners, purchasing agents, engineers and firemen.

COST ACCOUNTING THEORY AND PRACTICE. By James L. Dohr. Ronald Press Co., New York, 1924. Cloth, 5 × 8 in., 631 pp., $4.

Intended as a simple, well-rounded discussion of the principles and practices of cost accounting for use by students. The author attempts to keep the object of such accounting clearly before the student from the beginning and thus enable him to follow the details of cost procedure without confusion.

DIE DAMPFLOKOMOTIVE. By J. Jahn. Julius Springer, Berlin, 1924. Boards, 6 × 9 in., 356 pp., illus., 18 gold marks.

Beginning with Stephenson's "Rocket" and continuing the story to the present day, Professor Jahn gives an account of the way in which the modern locomotive has developed. Each change in design is illustrated by a cut of an actual locomotive and the novelty in the design is pointed out. The material is classified on the basis of wheel arrangement, so that the volume is convenient for reference use, as well as for study. It is intended for readers familiar with current designs and should prove useful to engineers and designers.

DESIGN OF RAILWAY LOCATION. By Clement C. Williams. Second edition. John Wiley & Sons, New York, 1924. Cloth, 6 × 9 in., 517 pp., illus., diagrams, maps, tables, $4.

This book is intended as a textbook and therefore is rather an outline than an exhaustive treatise. The explanation and development of underlying principles, rather than the description of current practice is the aim of the author. Considerable space is given to the principles of railroad economics. The book has been prepared with a view chiefly to the extensive revision and relocation of railroads now in process in the United States, but attention is also given to the projection of new location.

ELASTIZITÄT UND FESTIGKEIT. By C. Bach and R. Baumann. Ninth edition. Julius Springer, Berlin, 1924. Boards, 6 × 9 in., 687 pp., illus., diagrams, $5.75.

This treatise has become so well-known to engineers, during the thirty-five years since its first appearance, that it is scarcely necessary to do more than announce the appearance of a new enlarged edition. The reader will find a thorough discussion of the theoretical principles, accompanied by a wealth of numerical data obtained by experiment, and an interesting collection of photographs of test-pieces, showing the results after undergoing tests of various kinds.

ELEMENTS OF STATISTICS. By Frederick C. Kent. McGraw-Hill Book Co., New York, 1924. Cloth, 6 × 8 in., 178 pp., diagrams, tables, $2.

Written for persons without the mathematical equipment usually considered necessary for the study of statistics, but who nevertheless desire an introduction to statistical methods. The book treats such subjects as methods of collecting and tabulating data; the graphical portrayal of statistics; measures of central tendency, of dispersion and of correlation; and the normal distribution curve. The book is designed as a text for brief courses of instruction.

FERROUS METALS. By M. S. Birkett. 165 pp. NON-FERROUS METALS AND OTHER MINERALS. Two volumes. By N. M. Penzer. Cloth, 8 × 10 in., 264 pp. Ernest Benn, Ltd., London, 1924. 21s, each.

In these two volumes is presented a concise, authoritative review of the metal resources of the entire British Empire. The information is selected and presented with an eye to the needs of the business man rather than the specialist. It includes a general description of its metal, its properties and uses, information on the localities where it is found, and statistics on production, consumption, exports and imports. The volume on ferrous metals contains considerable historical information on the various products of iron and steel. The non-ferrous volume has an excellent selected bibliography on the metals considered.

GRAPHIC ANALYSIS FOR EXECUTIVES. By Winfield A. Savage. Codex Book Co., New York, 1924. Cloth, 5 × 8 in., 141 pp., charts, $4.

This book is designed to supply business executives with definite data upon the application of graphic methods to the analysis of the problems involved in business management. Charts for administrative control, sales charts, cost charts, budget-control charts, routine charts and organization charts are discussed and numerous examples are given in each case of forms that have given satisfaction. This is, the author believes, the first attempt to treat the problems of charting the statistics of a corporation from the viewpoint of the man within the corporation rather than that of the outside observer.

GRUNDBEGRIFFE DER MECHANISCHEN TECHNOLOGIE DER METALLE. By Georg Sachs. Akademische Verlagsgesellschaft M.B.H., Leipzig, 1925. Paper, 6 × 10 in., 319 pp., illus., diagrams, tables, $3.15.

This book is intended to give a survey of the great mass of information available on the mechanical properties of the metals used in construction, with its frequent apparent contradictions. The author's first object has been to group the results of the various researches with close regard to the conditions of the research; this has frequently been sufficient to reconcile apparent discrepancies.

It is chiefly confined to the basic, simple processes of treating metals. The mechanical properties of molten and solid metals are discussed, as are the effect of crystallization and the properties of crystalline aggregates, the effects of cold working and annealing,

and the mechanical properties of pure metals and alloys. A valuable list of references to the sources of the data used is included. The book is a useful collection of the information most needed by builders of machinery.

How to Build Up Furnace Efficiency. By Joseph W. Hayes. Joseph W. Hayes & Associates, Michigan City, Ind., 1924. Cloth, 5 × 7 in., 534 pp., illus., $3.

In vivid, slangy diction, with numerous humorous cartoons to illustrate his points, the author of this book presents in detail accepted practice in boiler-room operation. Because of its unconventional style and simple exposition, the book is well fitted to hold the interest of the reader, while the advice given cannot fail to prove profitable, if followed.

A Hundred Years of Portland Cement, 1824–1924. By A. C. Davis. Concrete Publications, Ltd., London, 1924. Cloth, 7 × 10 in., 282 pp., illus., diagrams, tables, $5.

In 1824 Joseph Aspdin of Leeds secured a patent for a cement which he named "Portland" cement, thus introducing the term that has become so common. But it was the name, rather than the Portland cement that Aspdin invented; for the material there seems to be no specific invention. Mr. Davis has written the history of the evolution of cement from Smeaton's experiments in 1756 onward. He notes the early investigators, describes the experiments that led up to the manufacture, the initial industry and the methods of manufacture at different periods. Chapters are included on standard specifications and on the specifications which have been adopted in various countries. Many photographs illustrate the history.

Introduction to the Economies of Air Transportation. By Thomas Hart Kennedy. Macmillan Co., New York, 1924. Cloth, 5 × 8 in., 154 pp., illus., $2.

The quality that air transportation offers in greater degree than other forms of transportation is speed. Is the addition of this desirable quality justified from the viewpoint of economics? Is air transportation a profitable business? If not, how can it be made profitable? Mr. Kennedy has devoted himself to a study of these questions and here presents the material that he has been able to collect. He sketches the history and technical features of aircraft, describes the Air Mail Service and the Aeromarine Airways line, as well as projected lines. He includes a record of his experiences as a passenger on European air lines in 1923 and data on European air transport lines and companies.

Leçons Sur La Composition et les Fonctions Permutables. By Vito Volterra and Joseph Pérès. Gauthier-Villars et Cie., Paris, 1924. Paper, 6 × 10 in., 183 pp., 20 francs.

Professor Volterra has already outlined the theories here developed in two previous books on integral equations and integro-differential equations and on the functions of lines. In those books, however, the concepts now presented, which have as their common origin the method given by him for solving integral equations, appear only indirectly and in application to the solution of certain problems in analysis and mathematical physics. In the present work the theory has been disengaged from the researches to which it was an auxiliary and is presented independently in more systematic and complete form.

Mathematics for Technical Students. By E. R. Verity. Longmans, Green & Co., London and New York, 1924. Cloth, 6 × 9 in., 468 pp., $4.

A textbook planned to meet the standard required for the "Senior course" certificate in engineering awarded by the Institution of Mechanical Engineers. The course covers algebra, trogonometry and the differential and integral calculus, and is intended for students with some knowledge of geometry.

Mechanics of Textile Machinery. By William A. Hanton. Longmans, Green & Co., London and New York, 1924. Cloth, 6 × 9 in., 236 pp., diagrams, $4.20.

A textbook dealing with the application of mechanics to textile machinery, intended for students of textile engineering and for designers and users of textile machines. Assumes a knowledge of elementary mechanics and of the general working of textile machinery. Most of the book deals with machinery for cotton spinning and weaving. Part one is devoted to that part of mechanics needed in studying the working of machinery. Part two deals with spinning machinery, part three with preparatory machinery, and part four with power looms. Part five is given over to discussion of machine drives and power testing of textile machines.

Scientific Research and Human Welfare. By Franklin Stewart Harris and Newbern I. Butt. Macmillan Co., New York, 1924. Cloth, 5 × 8 in., 406 pp., $2.50.

An account of some of the inventions and discoveries that make up the civilization of today, intended for general readers and written in popular style. Sections are devoted to health, communication, transportation, illumination, agriculture, engineering and mining, manufacturing and the home. In each section the great advances are recorded, with an account of the steps by which they were evolved. The ultimate purpose of the book is to call attention to the value of research in various lines and to plead for greater support of investigations.

Screw Propellers and Estimation of Power for Propulsion of Ships, also Airship Propellers. By Charles W. Dyson. Two volumes. Simmons-Boardman Publishing Co., New York, 1924. Cloth, vol. 1, 6 × 9 in.; vol. 2, 10 × 16 in., diagrams, tables, $15.

The third edition of this work differs materially from the preceding one. All the design curves given there have been discarded and new curves developed from equations derived from well-authenticated observations. This has resulted in new curves for basic apparent slip, based upon the hull of the ship and the ratio of the length of after body to draft. More attention has been given also to variations in hull form. This edition, Rear-Admiral Dyson states, is the last which he will prepare.

Statics, including Hydrostatics and the Elements of the Theory of Elasticity. By Horace Lamb. Second edition. University Press, Cambridge, England, 1924. Cloth, 6 × 9 in., 357 pp., diagrams, $5.75.

This textbook contains the substances of lectures given at the University of Cambridge for a number of years to students with some knowledge of elementary mechanics and ability to apply the methods of the calculus. Prominence is given to geometrical methods, particularly those of graphical statics. In this new edition, considerable additions have been made to the chapters on elasticity.

Study of the Locomotive Boiler. By Lawford H. Fry. Simmons-Boardman Publishing Co., New York, 1924. Cloth, 6 × 9 in., 157 pp., diagrams, tables, $4.

In this book the writer has attempted to take advantage of the information produced by the locomotive-testing plants, for the purpose of clarifying our knowledge of the operation of the locomotive boiler. For this purpose he has tried to devise a logical method for comparing boiler tests, and with this to study the distribution of heat through the boiler and consider the laws governing heat transmission in the firebox and flues. Formulas are derived and methods of analysis given which have checked closely with actual results in practice.

Sur L'Electrodynamique des Corps en Mouvement. By Albert Einstein. Gauthier-Villars et Cie., Paris, 1925. Paper, 5 × 7 in., 56 pp., portraits, 6 francs.

The memoir here republished in convenient form appeared first in 1905, in the Annalen der Physik. It is here that Einstein first explained his celebrated theory of restricted relativity. The volume forms one of a series of reproductions of great scientific papers.

Le Vol a Voile Dynamique des Oiseaux. By Louis Breguet. Gauthier-Villars et Cie., Paris, 1925. Paper, 6 × 9 in., 57 pp., 8 fr.

In this memoir, the author has attempted to establish rationally the first principles of flight in agitated air, limiting his discussion to a fundamental study of the mean rectilinear and horizontal motion of a plane subjected to periodic pulsations of the air, such as occur in winds. The problem is attacked by mathematical analysis. The theory developed is that proposed by the author in 1909, which differs from those of Mouillard and Langley and of Sée.

THE ENGINEERING INDEX

Registered United States, Great Britain and Canada

LAST-MINUTE ADDITIONS: MAIN BODY ON PAGE 123-EI., ADVERTISING SECTION

Exigencies of publication make it necessary to put the main body of The Engineering Index into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRCRAFT

Magnus Effect Applied to. Is the Magnus Effect Applicable to Aircraft, A. Klemin. Aviation, vol. 18, no. 5, Feb. 2, 1925, pp. 127–129, 7 figs. Modern aerodynamics and Magnus effect; aerodynamics of rotating cylinders; possible application to aircraft; it is shown that while application is worth thinking of, there are many difficulties, both aerodynamical and mechanical.

AUTOMOBILE ENGINES

Vibration. Measurement of Engine Vibration Phenomena, C. E. Summers. Soc. Automotive Engrs.—Jl., vol. 16, no. 2, Feb. 1925, pp. 163–171, 18 figs. Describes number of indicating and recording instruments devised for recording actual resultant vibration and determining its exact character; vibration due to unbalance of rotating parts; piston unbalance inherent in 4-cylinder engines; bending of crankshaft; centrifugal force and torsional periods; indicator diagrams of various kinds of vibrations.

AUTOMOBILE FUELS

Research. Recent Coöperative-Fuel-Research Progress, S. W. Sparrow and J. O. Eisinger. Soc. Automotive Engrs.—Jl., vol. 16, no. 2, Feb. 1925, pp. 237–242, 11 figs. Deals with further progress in coöperative fuel research; general factors underlying starting ability; effect of changes in spark character and gas leakage; probable mechanism of crankcase-oil dilution.

AUTOMOBILES

Balloon-Tire Effect on Design. Effects of Balloon Tires on Car Design, J. W. White. Soc. Automotive Engrs.—Jl., vol. 16, no. 2, Feb. 1925, pp. 205–208, 4 figs. Review of car design as affected by low-pressure tires; conclusion is reached that, in order to avoid shimmying, all backlash must be taken out of steering mechanism and that, so far as possible, all rake of king-pin outward leading of wheels, and toe-in should be eliminated; suggests introduction of hydraulic steering gear as means of accomplishing these results.

Bodies, Silent Flexible. The Weymann Silent Flexible Body, Geo. W. Kerr. Soc. Automotive Engrs.—Jl., vol. 16, no. 2, Feb. 1925, pp. 215–218, 8 figs. Body construction is of character such that wooden framework is secured by suitably shaped steel joining plates and bolts that separate wooden members 1/8 in. at joints; it is claimed that effect is to impart to body easy deformability and to permit it to accommodate itself to distortions of chassis frame, to which it is rigidly attached; quotes portion of English patent specification; details of actual construction practice at inventor's factory in Paris, France.

Shimmying. Wheel Shimmying: Its Causes and Cure, O. M. Burkhardt. Soc. Automotive Engrs.—Jl., vol. 16, no. 2, Feb. 1925, pp. 189–191, 4 figs. Definition and cause of shimmying; remedies suggested are: (1) design so that no slackness can develop; (2) design for rigidity; (3) use effective devices to absorb kinetic energy wherever it is likely to accumulate.

BLAST FURNACES

Hearth and Bosh Construction. Proposed Hearth and Bosh Construction, S. P. Kinney and F. B. McKenzie. Iron Age, vol. 115, no. 7, Feb. 12, 1925, pp. 476–478, 6 figs. Modern ideas applied to blast-furnace design for highest combustion efficiency; elliptical or similar section favored. Published by permission of Bur. of Mines.

Research Methods for. Research Method for Blast Furnaces, W. G. Imhoff and D. E. Ackerman, Iron Age, vol. 115, no. 3, Jan. 15, 1925, pp. 203–211, 12 figs., 6 tables. Use of symbols to designate observed conditions facilitates work; records capable of later intimate analysis.

BOILER FURNACES

Water-Lined Walls. Water-Lined Furnace Walls for Power Station Boilers. Engineering, vol. 119, no. 3081, Jan. 16, 1925, pp. 71–74, 12 figs. partly on supp. plate. Results of tests on boiler equipped with Murray water tubes, at Hell Gate station, New York.

BOILER PLANTS

Heat-Regeneration System. The Weir Heat Regeneration System. Power, vol. 61, no. 6, Feb. 10, 1925, p. 208, 1 fig. New method of carrying out principles of regeneration as applied to flue gases after leaving main boilers; low-pressure boiler, situated in uptake of main boiler, acts as feed heater, steam generator and feed reservoir in one.

Records. The Importance of Boiler Plant Records, F. M. Gibson. Indus. Mgt. (N. Y.), vol. 69, no. 2, Feb. 1925, pp. 86–88. How properly installed system cuts fuel bills from 5 to 35 per cent.

BOILERS

Heads under External Superpressure. Boiler Heads under External Superpressure (Dampfkesselböden unter ausserem Ueberdruck), C. Diegel. Zeit. des Vereines deutscher Ingenieure, vol. 69, no. 2, Jan. 10, 1925, pp. 41–43, 4 figs. Results of test on bumped head of larger diameter; comparison with results of previous tests on smaller heads indicates insufficient resistance.

CENTRAL STATIONS

Springfield, Mo. Revamping Station at Springfield, Mo., J. D. Bowles. Power, vol. 61, no. 5, Feb. 3, 1925, pp. 166–170, 5 figs. Water-sealed ashpits behind boilers one of outstanding features involved in modernizing and enlarging plant of Springfield Gas & Elec. Co.; other changes include increased steam pressure, water-cooled furnace walls, forced-draft cooling tower and live steam at 125 lb. to replace district heating with exhaust steam.

CONVEYORS

Layout in Factory. Arranging Machines and Conveyors for Flexible Production Schedules, Wm. Bailey. Am. Mach., vol. 62, no. 7, Feb. 12, 1925, pp. 257–260, 10 figs. Example of laying out conveyors to serve group of machines; automatic switching of work trays and prevention of traffic jams.

CUPOLAS

Charging. Charge Cupolas Mechanically. Foundry, vol. 53, no. 3, Feb. 1, 1925, pp. 111–113, 3 figs. Handling pig iron, scrap, and limestone is facilitated by mechanical equipment from unloading cars to charging cupola in Ohio pipe shop.

CUTTING TOOLS

Forces Exerted on Surface. Cutting Tools Research, T. E. Stanton and J. H. Hyde. Engineering, vol. 119, no. 3083, Jan. 30, 1925, pp. 148–150, 11 figs. Report on experimental study of forces exerted on surface of cutting tool. (Abridged.) Paper presented before Instn. Mech. Engrs.

DROP FORGING

Steel Problems. Some Steel Problems in the Drop Forging Industry, M. H. Schmid. Forging—Stamping—Heat Treating, vol. 11, no. 1, Jan. 1925, pp. 2–7. Points out that close coöperation and thorough understanding between drop forger and steel producer is necessary to meet existing demands; chemical composition of steels for forgings; care required in heat treating; alloy steels; inspecting shipments; defects in rolled steel; case-hardening test; microscopic study; x-ray and magnetic testing; selection of forging steels; cold shuts and laps; etc

FACTORIES

Building Design. Tendencies in Building Design. Factory, vol. 34, no. 1, Jan. 1925, pp. 49–52 and 210, 3 figs. Tendencies in modern factory design; trend is said to be toward survey of actual building necessities before going ahead; comments on five phases of problem; present attitude toward plant location, one-story vs. multi-story buildings, and such details as roofs, materials of construction, and employee consideration.

GAS ENGINES

Combined Gas Compressor and. Combined Crankless Gas Engine and Gas Compressor. Engineering, vol. 119, no. 3082, Jan. 23, 1925, pp. 104–106, 7 figs. partly on p. 108. Design is due to A. G. M. Michell who realized that principle embodied in his thrust block made it practicable to revive swash-plate type of prime mover; with Michell pads, in which effective lubrication is ensured by rational design, friction is extraordinarily low, and very large loads can be carried on pads of small dimensions.

HOBS

Gear-Cutting. A Gear Cutting Hob of Novel Construction. Am. Mach., vol. 62, no. 5, Jan. 29, 1925, pp. 207–209, 6 figs. Hob is made up of five sections; each section is separate drop forging; cutting edges are inserted tool bits; sections are interchangeable.

INDUSTRIAL MANAGEMENT

Distribution Methods. Improved Distribution Pays Big Dividends to Industry, E. L. Shaner. Iron Trade Rev., vol. 76, no. 7, Feb. 12, 1925, pp. 443–445 and 454, 4 figs. Deals with improvements made in interests of more efficient distribution.

Foundries. Getting Castings Out on Schedule. Iron Age, vol. 115, no. 3, Jan. 15, 1925, pp. 193–196, 7 figs. Planning and controlling production in plants of all sizes; aids in determining costs; improving production inspection.

Power-Cost Reduction. "How We Reduced Our Power Costs." Indus. Mgt. (N. Y.), vol. 69, no. 2, Feb. 1925, pp. 112–115. Experiences in cost reduction as revealed by this journal's prize contest.

Task Setting, Time Allowances in. A New Graphical Solution, C. G. Barth. Mgt. & Administration, vol. 9, no. 2, Feb. 1925, pp. 143–144, 1 fig. Chart for calculating time allowances in task setting.

INDUSTRIAL PLANTS

Planning Buildings. Planning the New Building, A. G. Anderson. Mgt. & Administration, vol. 9, no. 2, Feb. 1925, pp. 117–120, 3 figs. In design and construction of plant, correct technical combination of materials, choice of materials, and actual construction work, are all important; but more so is consideration of physical layout from every angle, considering impress which it will make upon human element which will operate it.

INTERNAL-COMBUSTION ENGINES

Pinking in. Some Experiments on Gas Explosions in Closed Tubes, with Particular Reference to "Pinking," J. D. Morgan. Automobile Engr., vol. 15, no. 198, Jan. 1925, pp. 27–31, 14 figs. Results show that audibility which in author's opinion is identifiable with pinking in internal-combustion engine, is attributable to energetic vibrational motions in gas during process of combustion; vibrational motion depends upon two factors, and suitable variation of either factor will increase or decrease tendency to pinking.

JIGS

Cost Estimation. Estimating the Cost of Jigs and Fixtures, Wm. F. Sandmann. Machy. (N. Y.), vol. 31, no. 6, Feb. 1925, pp. 427–428, 2 figs. Describes estimate sheet devised by prominent machine-tool builder.

LUBRICATION

Power Plants. Can We Standardize Power Plant Lubrication, A. F. Brewer. Indus. Mgt. (N. Y.), vol. 69, nos. 1 and 2, Jan. and Feb. 1925, pp. 19–23 and 70–75, 10 figs. Jan.: What lubricant specifications mean; discusses characteristics of various oils and compounds and what these characteristics mean. Feb.: Specific requirements of various types of prime movers.

MACHINE SHOPS

Layout. A Modern Shop Planned for Building Automatic Printing Presses, Wm. M. Kelly. Am. Mach., vol. 62, no. 7, Feb. 12, 1925, pp. 281–284, 3 figs. Aims in planning shop; progressive production by continuous-flow method; machines arranged to suit both machine and product departments, according to work.

MACHINING METHODS

Machine-Tool Production. Tooling Methods. Engineering, vol. 119, no. 3081, Jan. 16, 1925, pp. 85–87, 18 figs. Deals with exhibit of Alfred Herbert, Ltd., at Olympia, which related more to production methods than to mechanisms utilized; typical repetition jobs were handled.

MATERIALS HANDLING

Forgings. Economical Handling of Material, E. Tonkin. Forging—Stamping—Heat Treating, vol. 11, no. 1, Jan. 1925, pp. 24–26, 6 figs. Discusses material handling, comparison of electric truck and gasoline tractor and design of tote boxes, racks and trailers.

PISTONS

Automobile. Making Pistons in the Locomobile Shop, N. A. Jagger. Am. Mach., vol. 62, no. 5, Jan. 29, 1925, pp. 183–185, 7 figs. Operations planned to secure smooth flow of work; rough turning, grooving and boring done on semi-automatic machines; compact set of turret-lathe tools.

Friction of. The Friction of Pistons and Piston Rings, T. E. Stanton. Engineer, vol. 139, no. 3603, Jan. 16, 1925, pp. 70 and 72. From results of experiments, it appears that lubrication of piston rings is of boundary type, and that their frictional resistance will depend on normal pressure between rings and cylinder wall; it is clear, therefore, that any device which will prevent leakage of gas or steam from back of piston to space behind piston rings will improve mechanical efficiency of engine.

PRESSWORK

Blanking Tools. Blanking Tools for Pressed Steel, W. E. Irish. Machy. (N. Y.), vol. 31, no. 6, Feb. 1925, pp. 451–453, 4 figs. Describes what might be called temporary blanking tools, making of which involved only small investment, and which practically eliminates tools themselves from being any considerable item in cost of part.

RAILWAY SHOPS

Car-Shop Work. Maintenance of Rolling Stock on New England Railroads, E. Sheldon. Am. Mach., vol. 62, no. 7, Feb. 12, 1925, pp. 269–271, 6 figs. Work in railway-car shops; new construction as well as repairs; freight, passenger, dining, mail and baggage cars.

ROLLING MILLS

Electric Drive. Main Roll Drives in the United States and Canada. Iron & Steel Engr., vol. 2, no. 1, Jan. 1925, pp. 29–54. Tabulated list of main roll drives installed in iron and steel industry; information is presented in uniform manner showing horsepower, r.p.m., voltage, cycles, type and size of mill, method of drive, date of purchase, name of plant and location; also classified list giving types of installations in different kinds of mills; tabulation of multi-speed drives, a.c. speed sets, d.c. adjustable-speed drives and reversing blooming mill drives.

TURBO-GENERATORS

Efficiency Test. Efficiency Test of a 15,000-Kilowatt Turbo-Generator, J. E. Woodwell. Power, vol. 61, no. 4, Jan. 27, 1925, pp. 128–131, 8 figs. Test of two-hour duration run at various loads on turbine of Municipal Power Plant at Lansing, Mich.; summary of results.